THE RHINO WORKCELL

USER'S MANUAL

Version 1.02 April 4th, 1986

RHINO ROBOTS INC.

Workcell Part Number FG 1331
Manual Part Number 65-60-1361

Authors:
H. S. Sandhu
Carl Phillips
Tom Hendrickson

Documentation Services,
Rhino Robots Inc.
P. O. Box 4010,
Champaign, Illinois. 61820
U. S. of America
Tel: 217-352-8485.
Telex: 3734731 RHINO ROBOTS C

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INTRODUCTION

A robot is almost never used as a stand alone device.

A robot is almost never used without other automated equipment.

Robots work in workcells. The workcell is the **environment** within which robots work. Within this environment they serve and are in turn served by other automatic and/or computer controlled equipment. In the workcell, the robot usually takes the place of the human being. As such, the robot usually serves the needs of the machines in the cell. That is also what the human operator does most of the time... **serve the machinery** that he or she is operating.

In order to be able to serve the machinery well, the operator is made familiar with the operations to be performed and knows when to feed or empty a machine. The familiarity that he has, is gained through years of experience and formal training. Now we want a robot to take over this tedious, repetative work. What do we have to do, to enable the robot, to do this?

Basic Requirements: There are a number of basic requirements that have to be fulfilled. Among them the following are the most important.

1. The robot selected has to be able to manipulate the parts and materials being used in a manner that will be similar to what the human operator does for this particular application. This is a function of the design of the robot.

2. The robot has to have an instruction set that allows us to

program it to do the work that we want done. The instruction set is the language of the robot. The instruction determines what we can tell the robot to do.

3. The robot has to have a way of being told when to start and stop doing the work that needs to be done. This controlled by the input and output capabilities of the robot.

4. The machines that the robot works with have to be able to tell the robot when to start or stop doing the work that needs to be done. They have their own input/output that allows them to do this.

5. The robot has to be able to tell the machines what it is working with and when to start or stop doing the work that needs to be done. This too is handled through the input/output.

6. Detectors have to provided to serve as the ears, hands and eyes of the robot. These detectors are tied into the I/O to tell the robot what is occuring.

As stated above, all this communication between the machinery is handled with what we call I/O (Input/Output). Each machine has a number of inputs that it can respond to and each machine has a number of outputs that it can manipulate. The output from one machine is usually the input into another machine and vice-versa. So the signal is either an input or an output depending whether it is going into the machine or coming out of the machine. The inputs and outputs can be ON-OFF devices or they can be variable signals. The less expensive machines would tend to use ON-OFF signals.

Programmable Controllers: Often the workcell is so complicated, that the I/O is handled by special computers that are designed specifically for handling I/O. These specialized computers are called **Programmable (Logic) Controllers**. On the factory floor they are referred to as **PLCs or PCs**. This is distinct from the use of the term PC to describe a personal

computer. In this discussion we will restrict the meaning of PLC to Programmable Logic Controller.

It is necessary to have all the I/O handled by a PLC because the computers that are controlling the robot are too busy with the many real time tasks required by the robot itself. The same is true of other automated equipment like CNC (Computer Numerically Controlled) machines like lathes and milling machines. The I/O interaction required by these machines is usually limited to telling the machine when to start and when to stop on the input side and to telling the PLC when the work in progress is completed so that the next operation can be initiated on the automatic machine side. Usually the PLC handles everything else.

The Typical Workcell: So, the typical robotic workcell consists of a robot, a PLC, maybe a CNC lathe, a CNC milling machine, a conveyor bringing work to the workcell and one going from the workcell to the next station. A sophisticated system might have vision support for the robot and may have an automated inspection station to confirm that the work was actually done as

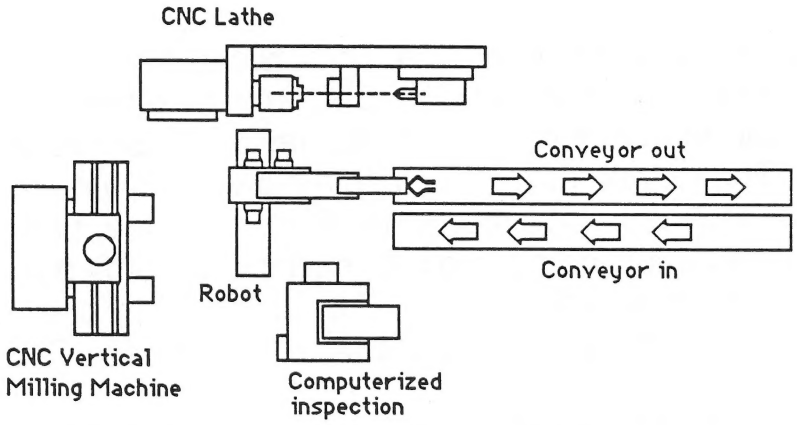


Figure 1
A Typical Flexible Manufacturing Cell

specified. Such an arrangement might also be called a flexible

manufacturing or machining cell (FMC). For our purposes it is a workcell for the robot. A cell of the type described above would be able to perform the necessary machining operation for most manufactured items requiring lathe and milling machine work. Other cells might concentrate on assembly or welding and painting operations as their main focus.

In the case of the Rhino XR robot and it's Mark III controller, the user has two options for working with and handling the I/O. The controller has the ability to respond to sixteen input lines (8 are for the user, 8 are microswitches, one on each motor ports) and can control 8 output lines. These lines can either be connected directly to the control functions desired **or** they can be routed to a PLC. Rhino's RoboTalk™ Language supports complete I/O capability and can be used to control all aspects of the Mark III Controller.

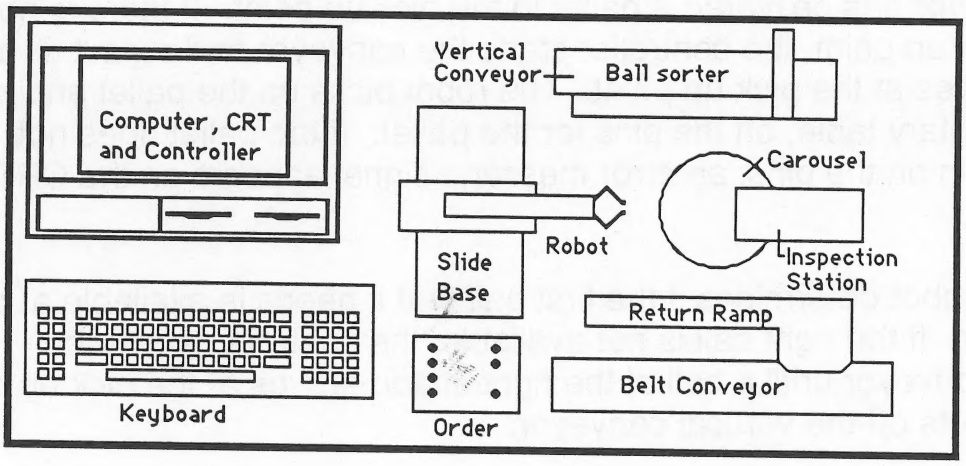


Figure 2
The basic layout of the Workcell.

The Workcell: The workcell is designed to introduce students and trainees to the basic techniques used in the design and use of workcells and robots.

The basic layout of the workcell is as shown above.

WHAT THE WORKCELL DOES.

The Rhino Workcell is designed to perform a sophisticated palletizing and order checking operation. The operator orders a pallet with either one or two ping-pong balls on it. The workcell system has both light and dark ping-pong balls in it. The operator specifies the coloring of the balls to be palletized. He can ask for light or dark units or he can ask for one of each. He or she also specifies whether the cell is to cycle once or to run continuously.

The information is entered at an order center.

The robotic system reads the information entered and then looks to see if the conveyor has delivered a pallet to the pick up point. If there is no pallet at the pick up point, the controller starts the conveyor and runs it till a pallet arrives at the pick up point. The robot picks up the pallet and places it on the rotary table, on the pins for the pallet. If the pallet does not settle down on the pins, an error message signal appears on the CRT of the computer.

Next the robot determines if the first ball that it needs is available at the ball sorter. If the right ball is not available, the controller starts the vertical conveyor until a ball of the right shade arrives at the pick up point. It then shuts off the vertical conveyor.

The robot picks up the required ping-pong balls and places them on the pallet.

After the robot moves out of the way, the rotary table is rotated to bring the pallet under the inspection station. The controller then inspects the pallet to make sure that a ball(s) is present and that each one is of the shade that was originally specified at the order center.

If the order is right, the green "order O.K." light is turned on. If the order is wrong, the red "order **not** O.K." light is turned on and the system makes the necessary moves to correct the situation automatically. All conditions encountered are annunciated at the computer CRT.

After a correct order has been assembled, the robot unloads the pallet and puts all items back in their respective feeders, ready for the next order.

The workcell demonstrates the operation of an intelligent workcell. The workcell can be programmed in a number of different ways, in a higher level language, by students and trainees who are are learning about robotics and robotic languages.

Besides allowing programming in a higher level language, the workcell trains the students in the field of robotics and automation to think in terms of the special requirements of machines that interact with one another. Though a well designed and implemented task looks trivial to the un-initiated observer, the requirements are quite complicated. Notice that there are a very large number of detectors on the workcell. Each one gives the system a specific piece of information about what is going on in the cell. The computer uses this information to make decisions about the task being executed.

The components of the workcell may be arranged in other ways to create other workcell configurations. Advanced students can modify the existing workcell as may be required to add other capabilities to the system. Other accessories needing either encoded or unencoded motors can be made by the students as might be needed to effect the manipulations that the cell requires.

UNPACKING THE WORKCELL

The workcell consists of an integration of standard Rhino XR accessories

with the other items needed to create the workcell. The unit is shipped as the following major systems:

1. The XR robot.
2. The Mark III controller.
3. Linear slide base
4. Rotary carousel and inspection station.
5. Belt conveyor with I/O modules and pallet return.
6. Vertical conveyor with ball return and sorter.
7. Package containing miscellaneous items.
8. Base for top surface.
9. Top surface that all parts are mounted on.

Each standard Rhino XR Accessory has its own manual and that manual should be consulted for information about that particular accessory. These manuals come with the workcell. The main Workcell Manual contains information about putting the various parts together to create the workcell. (The vertical conveyor does not have a separate manual. It is considered a part of the work cell.)

The following general assembly sequence will be followed.

1. Unpack all items and place them on a work surface.

2. Place the base where you want to locate your workcell. Note that the workcell will require 115 VAC power. Position the unit near a power outlet. (A total of three items need to be plugged in; the computer, the Mark III Controller and the ball sorter.)

3. Place the table top on the workcell base.

4. Mount the workcell items on the workcell surface and secure each item in the following order:

   A. Horizontal belt conveyor and pallet return

B. Linear slide base
C. Order center
D. Rotary carousel and inspection station
E. Vertical conveyor, ball sorter and ball return
F. The robot and Mark III Controller with Teach Pendant and I/O
G. The host computer. The IBM-PC and Apple IIe are supported by Rhino but other computers may be used also.
H. Wiring.

5. Go through the test procedure for each item.

6. Wire the items together as shown in the manual.

TOOLS NEEDED

You will need the following tools to put your workcell together:

1. A large screwdriver for the screws that hold down the various parts of the workcell to the table top.

2. A small screwdriver to wire to the connectors at the various points. This has to be a fairly small unit if it is going to fit in the screw holes on the connectors of the PC boards.

3. A Rhino tool kit consisting of a set of Allen wrenches for the socket head screws.

4. A 1/4" electric drill and drill bits for making holes in the top of the work surface if modifications are to be made.

5. A set of combination wrenches from 1/4" to 5/8" for various nuts and bolts that might need to be tightened.

6. A high impedence volt meter to measure voltages at the detectors and for calibration and testing.

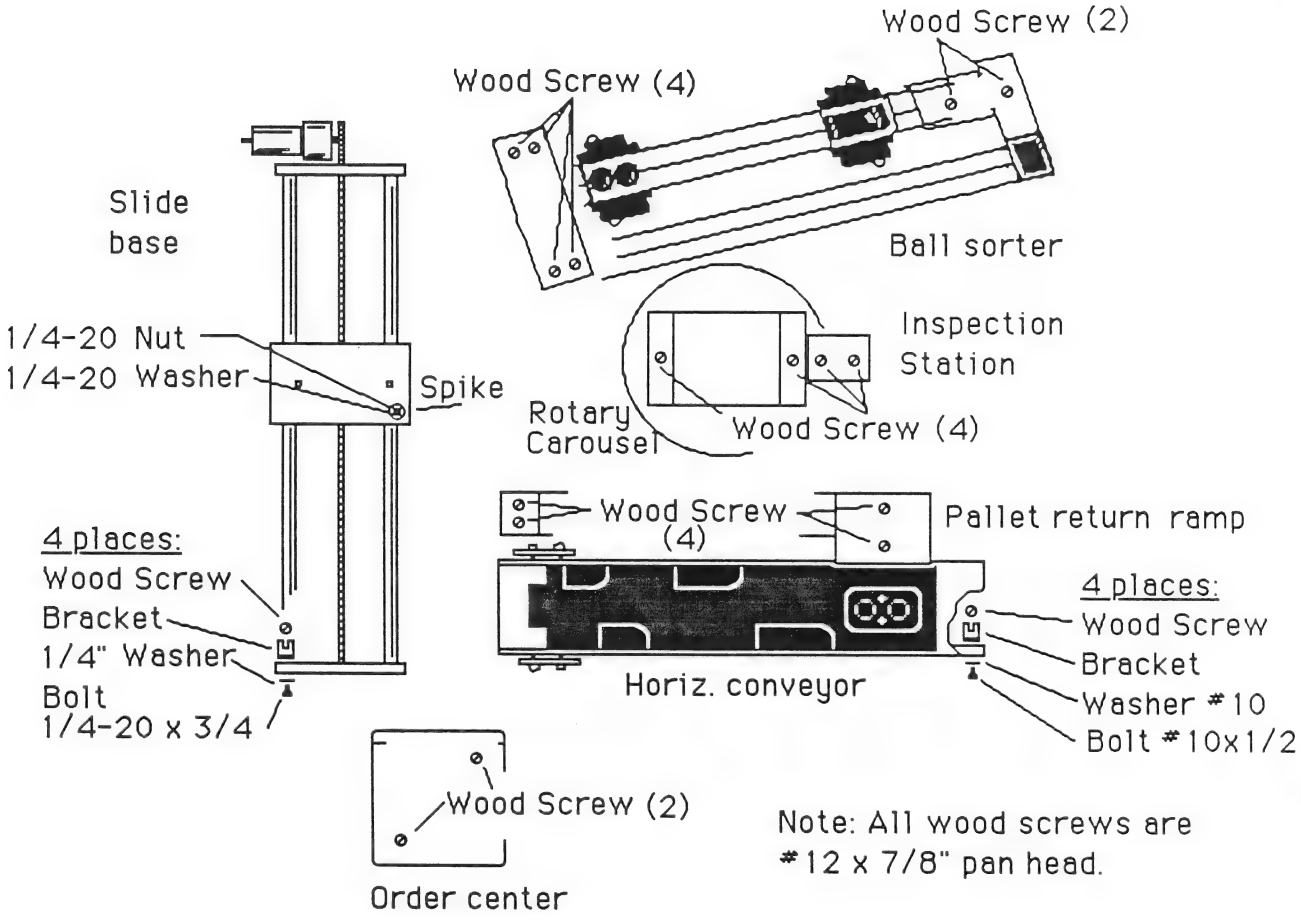
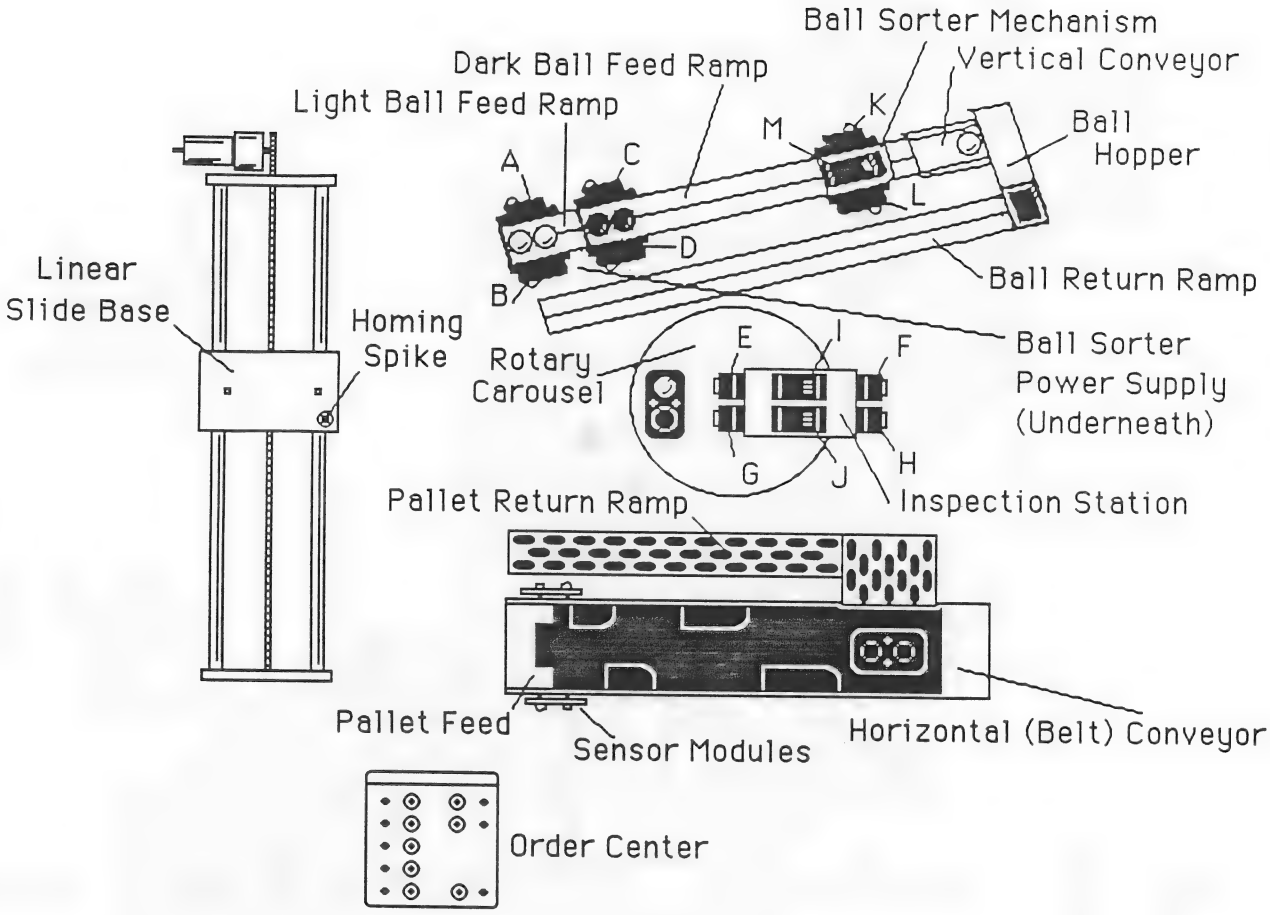


Figure 3 THE RHINO WORKCELL MOUNTING DIAGRAM



Mark III Controller Port Definitions

A-F: Standard XR-2 Configuration
G: Linear Slide Base
H: Rotary Carousel
Aux 1: Vertical Conveyor (Switch DOWN)
Aux 2: Horizontal (Belt) Conveyor (Switch DOWN)

Inputs

1
2
3
4 — Order Center Data
5 Order Check Data, Pallet Seating Check
6 Pallet Detect (Conveyor)
7 Dark Ball Detect
8 Light Ball Detect

Outputs

1 Order Center Data Latch
2
3
4
5 — Inspection Station Order Dat
6 nc
7 Accept Lamp
8 Reject Lamp

Figure 4 THE RHINO WORKCELL

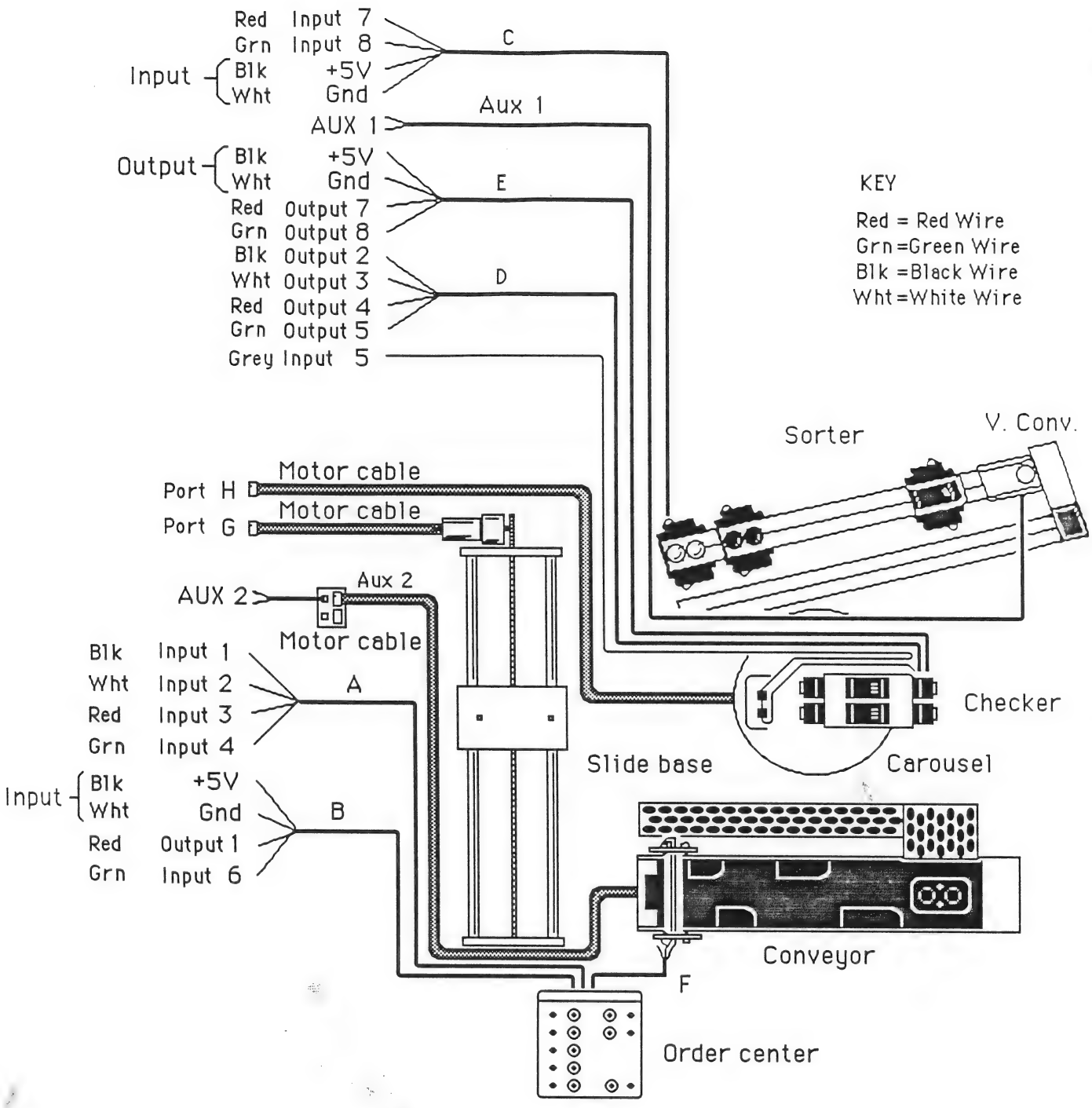


Figure 5 THE RHINO WORKCELL WIRE ROUTING DIAGRAM

THE HORIZONTAL CONVEYOR

PURPOSE

In the workcell, the horizontal conveyor acts a device for feeding the empty pallets to the robot whenever they are needed. The pallets are fed from one end of the conveyor. A pallet return ramp is used to return the used pallets to the other end of the conveyor. An optical detector provides the signal to indicate that a pallet is ready to be picked up. Static devices that orient the pallets are placed along the top of the conveyor.

CONTROL

The conveyor motor is controlled as an on/off device by the controller from Aux 2. The controller can read the presence of a pallet at the down stream end of the conveyor by reading the optical I/O module. (Input #6)

MOUNTING THE HORIZONTAL (BELT) CONVEYOR AND PALLET RETURN RAMP

Attach the pallet stop plate to the end of the horizontal conveyor away from the motor with two 6-32 x 1/4 BHCS. Be sure the slotted end is as close to the belt as possible without touching it. Refer to figure 7. Also attach the 5 pallet orienters using ten 8-32X1/2 SHCS. Refer again to figure 7 and make sure the orientation of the pallet orienters matches that of the diagram. The numbers next to the pallet orienters in the diagram refer to the number of holes along the top edge of the side plates with the first hole being nearest the pallet stop plate.

Fasten the 4 mounting brackets to the table top of the workcell and position the conveyor over the brackets. Refer to the Rhino Workcell diagram for positioning the conveyor. Attach the conveyor to the brackets using a washer and a 10-32X1/2 SHCS. Refer to figure 8. You may wish to first lay the motor cable down under the conveyor such that the motor cable end comes out from under the end of the conveyor with the pallet stop plate.

Referring to figure 7, attach the 2 sensor modules to the conveyor. Make sure the IR-LED and phototransistor (covered in heat shrink tubing) are peeking through the holes in the side plate. Be sure the modules are mounted such that the optic sensors are nearest the top of the conveyor and that the red LED is nearest the bottom.

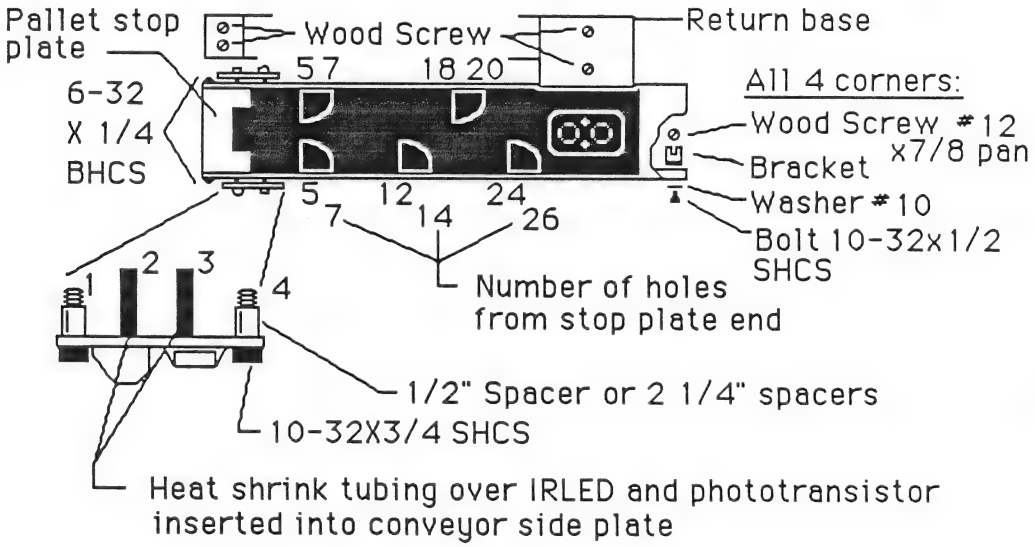


Figure 6
Horizontal conveyor, pallet sorter, pallet stop plate and sensor module mounting.

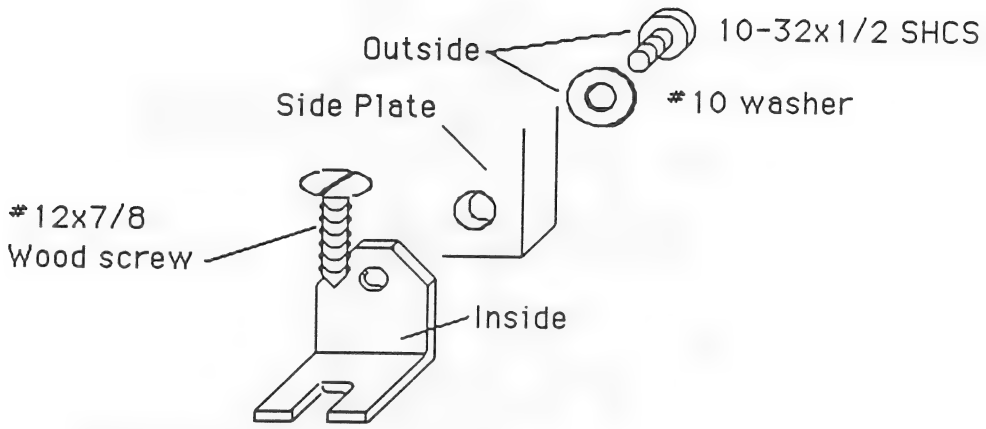


Figure 7
Horizontal Conveyor mounting bracket assembly.

The Pallet Return Ramp comes completely assembled. Remove the 4 screws holding the long ramp (2 at one end, 2 underneath the ramp at the end nearest the short ramp) and set the ramp aside. Remove the 5 screws holding the short ramp and set the ramp aside. Mount the base of the return ramp onto the workcell base with 4 wood screws or bolts refering to the Rhino Workcell diagram for positioning. Replace the long and short ramps.

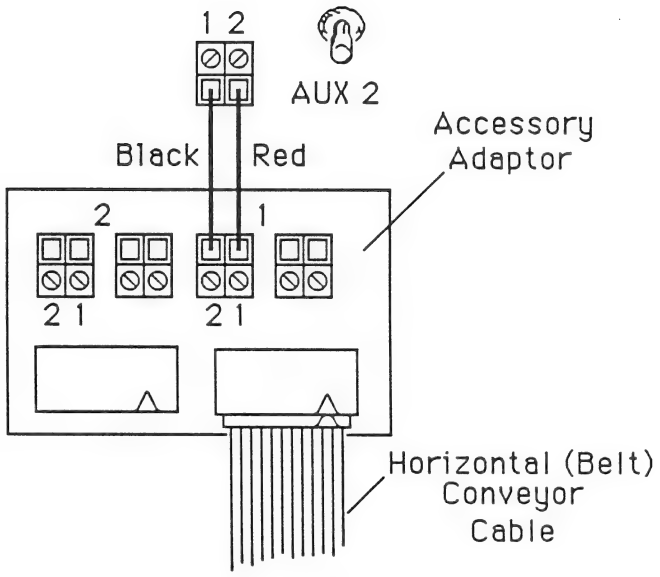
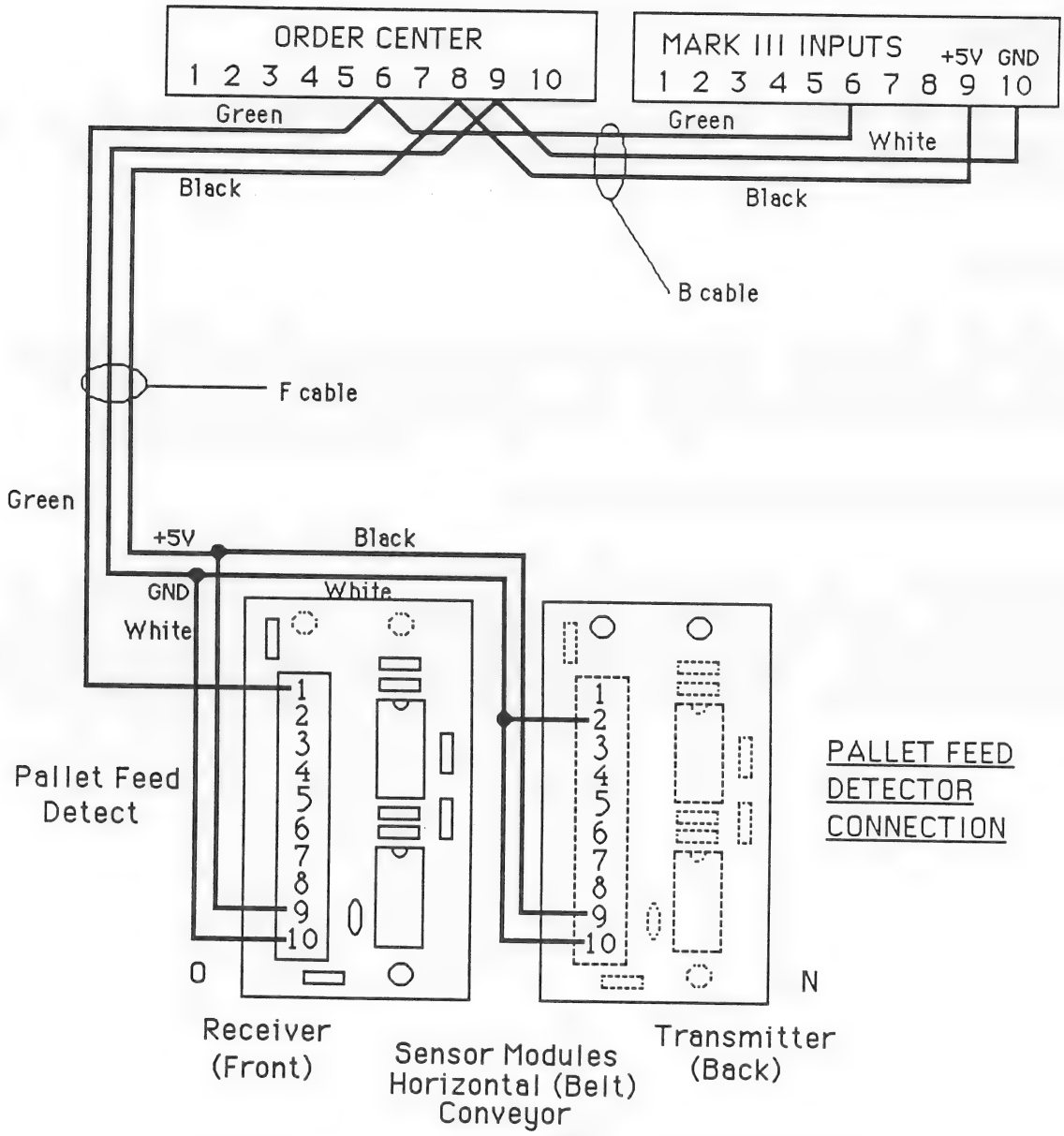


Figure 8
Horizontal conveyor connections

For AUX 2, the switch controls the direction of motion of the horizontal conveyor, normally the switch is in the down position.

Note: Toggling the AUX switches when the aux ports are ON is not recommneded. This can cause a voltage spike to enter the controller circuitry and cause loss of communication with the host computer. If this happens, you will have to reset the entire system and start over.



Input 6: 1 = Pallet available at end of conveyor.
0 = No pallet available.

Figure 9 PALLET FEED DETECTOR CONNECTION

THE LINEAR SLIDE BASE

PURPOSE

The linear slide base serves to extend the reach of the robot by providing lateral movement at the base. This allows the robot to serve a larger workcell.

CONTROL

The linear slide base is controlled as an accessory with an optically encoded motor. It is controlled from port "G". Using the optically encoded motor to run the linear slide base enables fine positional control of the robot.

MOUNTING THE LINEAR SLIDE BASE

The platform on the Linear Slide Base must have a spike mounted at the corner hole that will be closest to the Horizontal (Belt) Conveyor. Refer to figures 10 and 12. The spike must be mounted before attempting to mount the slide base itself. The spike is used to aid in homing the robot system.

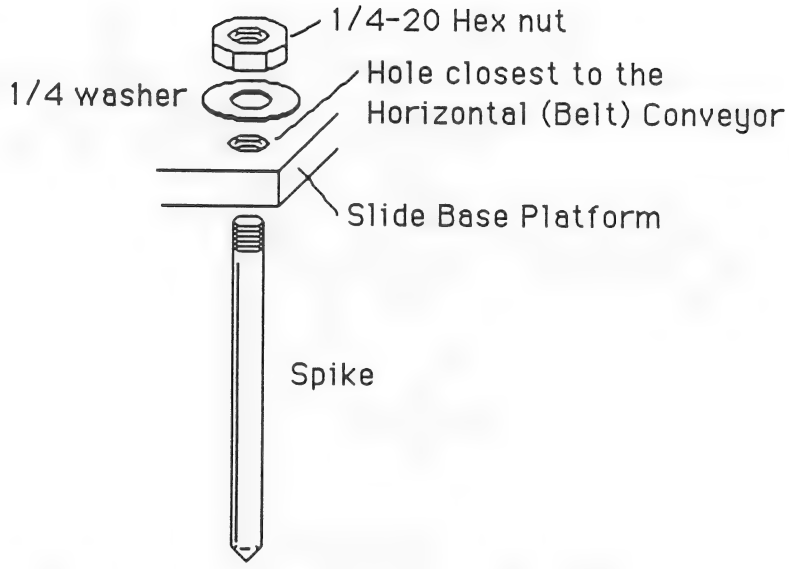


Figure 10
Linear Slide Base homing spike assembly.

The Linear Slide Base is mounted to the workcell base using 4 sets of brackets. See figure 12. Refer to the Rhino Workcell diagram for positioning the slide base. Note in figure 11 that all brackets are mounted on the end plates such that they are "inside" the slide base. Note also that the brackets used to mount the slide base are different from the brackets used to mount the Horizontal (Belt) Conveyor and should not be intermixed.

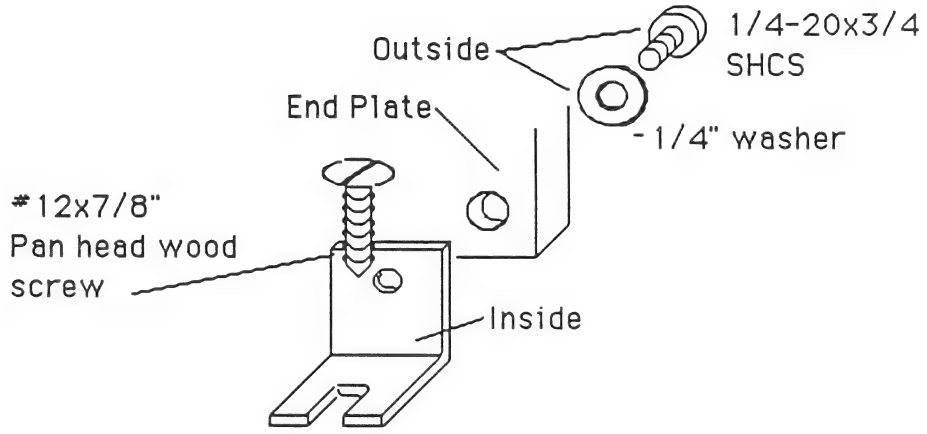


Figure 11
Linear Slide Base mounting bracket assembly.

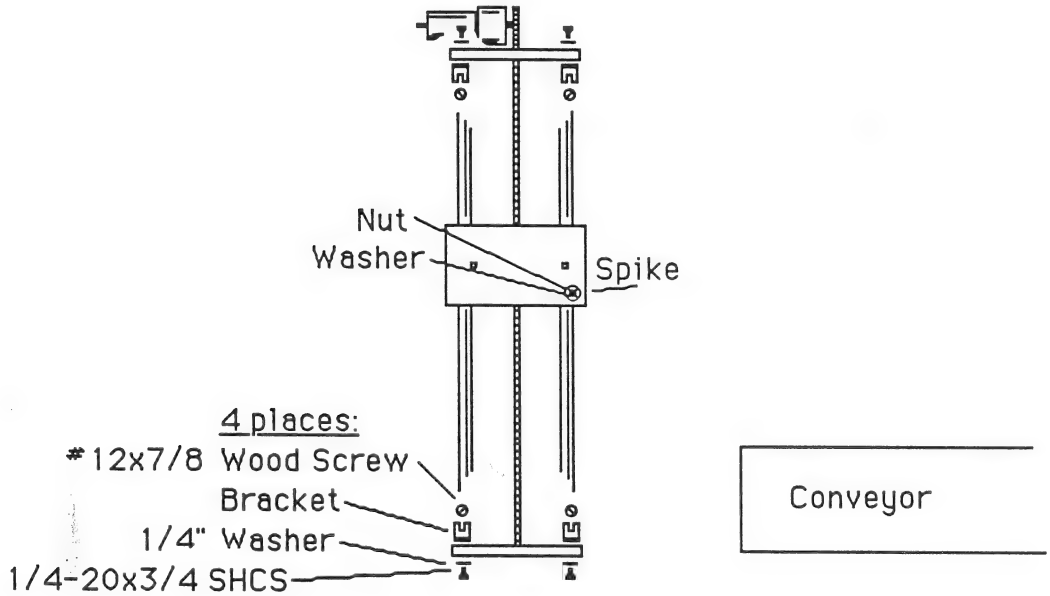


Figure 12.
Linear Slide Base mounting diagram.

TESTING THE SLIDE BASE:

Plug the Linear Slide Base's motor cable into port "G" of the Mark III Controller. Make sure the mode switch is in the up (Teach Pendant) position. Use the teach pendant's "G" motor move key to move the slide base platform back and forth. If the motor runs away, the most likely cause is the motor encoder optics. A quick check to test this possibility is to plug the motor cable into a different port (but not the "A" port) and use the pendant again. If the motor operates correctly, then the controller is at fault and you should contact Rhino Customer Service. If the motor still runs away while a known good motor works well in the same port, the problem is most probably in the motor's encoder optics.

THE ORDER CENTER

PURPOSE

The order center serves as the interface between the operator and the workcell. This is where the operator tells the workcell what needs to be done. In an automated system, this might be the point where the control computer or programmable controller interacts with the workcell.

CONTROL

The operator has the following control options:

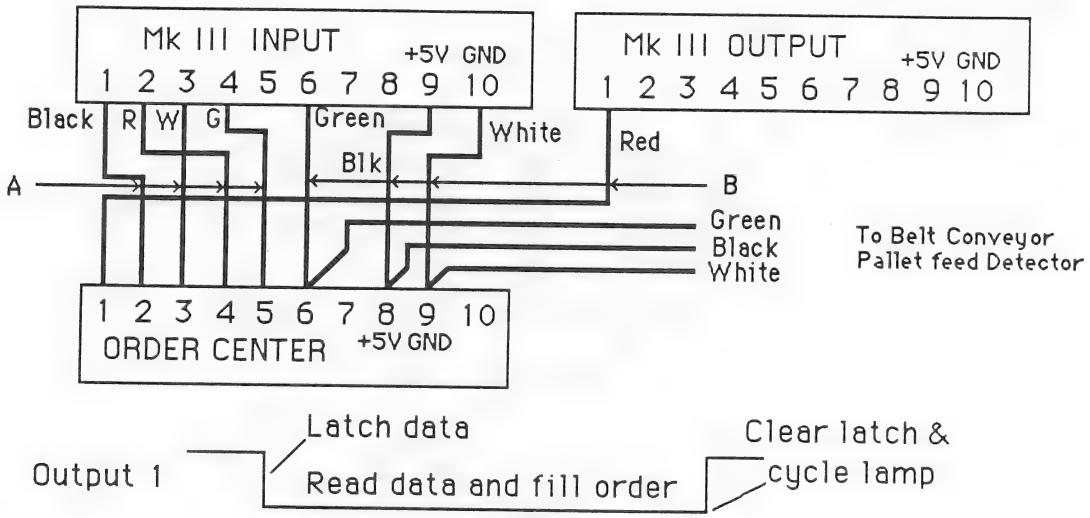
1. Order one dark ball
2. Order one light ball
3. Order one light ball and one dark ball
4. Order two light balls
5. Order two dark balls

6. Request one cycle
7. Request continuous operation

8. End program.

MOUNTING THE ORDER CENTER:

The Order Center is shipped with the top case already fastened to the bottom case by 4 screws. Remove the 4 screws and set the top aside. Take the bottom case and mount to the workcell base with 2 wood screws. Refer to The Rhino Workcell diagram for placement. Re-attach the top to the bottom case with the 4 original screws. Refer to the Order Center Connection diagram (figure 13) and connect the Order Center to a Mark III Controller being sure that all power is off.



Order Center Outputs		Controller Inputs 1324 / Order Center Outputs 2345	Final Selection
5	1 = Dark balls	0000	---
	0 = Light balls	0001	1 of each
3	1 = 2 balls	0010	---
	0 = 1 ball	0011	1 light
4	0 = 1 of each	0100	---
	1 = Not 1 of each	0101	1 of each
2	1 = Selection made	0110	---
	0 = No selection made	0111	2 light
		1000	---
Controller Inputs		1001	1 of each
		1010	---
1	1=Cycle or Run	1011	1 dark
	0=No Cycle or Run	1100	---
2	1=Not 1 of each	1101	1 of each
	0=1 of each	1110	---
3	1=2 balls	1111	2 dark
	0=1 ball		
4	1=Dark		
	0=Light		

Figure 13 ORDER CENTER CONNECTION

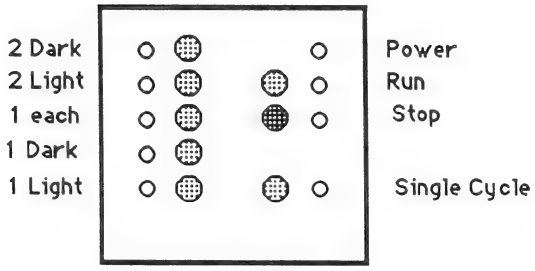


Figure 14
The order center.

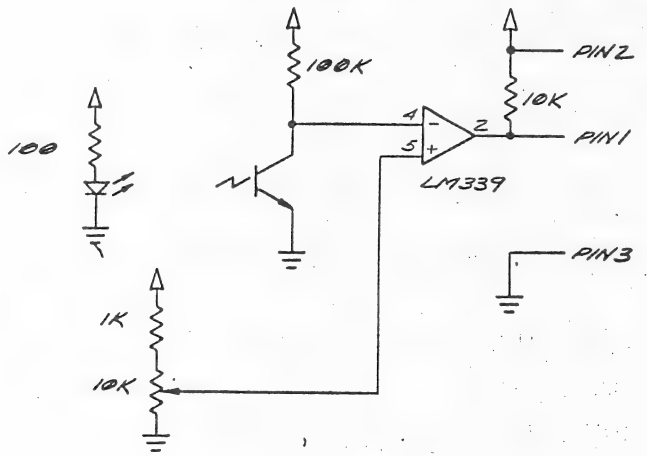
PRETESTING THE ORDER CENTER:

Turn the Mark III Controller on. The red "ON" lamp on the Order Center should be lit. If it doesn't, turn off all power and recheck all connections. Press each yellow button in succession. The yellow LED next to the pressed switch should light up with any other previously lit yellow LED turning off. Press the single cycle button. The green LED next to it should turn on (it will only turn off under program control or by removing power). Press the run button. The green LED next to it should be lit. Pressing the stop button should turn the LED off. If any of these procedures do not produce the desired results then the Order Center is faulty and you should contact Customer Service.

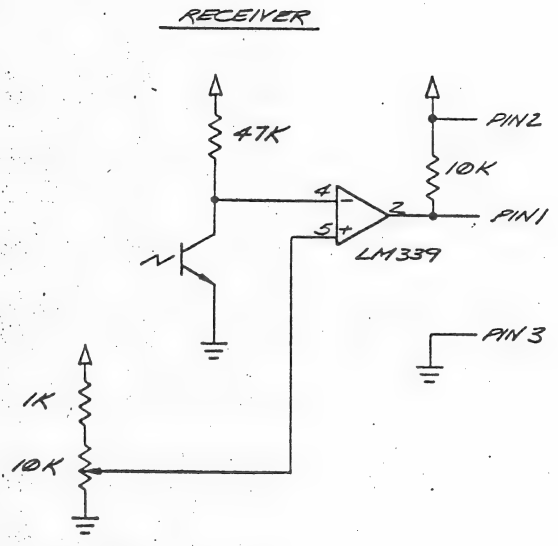
ORDER CENTER TEST PROGRAM:

With a host computer attached to the Mark III Controller, boot up RoboTalk™ and run the program called "TSTORDER". The monitor screen should first clear then display the current status of the Order Center. No order will be recognized until the run or single cycle buttons are pressed. If you press the run button you can press any yellow button and the screen should show the corresponding selection. Pressing the stop button will cause the screen to show no selection. If you press the single cycle button the screen will briefly flash the order that was selected and then display no selection. At

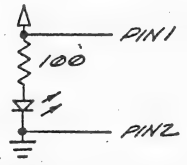
LEVEL DETECTOR



RECEIVER



TRANSMITTER



REV.	DESCRIPTION	DATE	BY	APPROVED

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2505 S. NEIL ST.
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(217) 352-8485

TITLE: OPTICS CONFIGURATIONS

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RJD			1-86

DO NOT SCALE DRAWING

DWG. NO.

the same time the green LED next to the single cycle button should turn on then off. (You may find it necessary to briefly hold down the single cycle button to give the computer time to recognize it. However, holding it down too long may result in multiple single cycles.) If the screen does not display the expected results, shut down all systems and recheck all connections. If you still encounter problems, contact Customer Service.

ROTARY CAROUSEL and INSPECTION STATION

PURPOSE

The rotary carousel provides a means of transfering a pallet, that has been filled with an order, to an inspection station.

CONTROL

The carousel is controlled through port "H" as an "encoded motor" driven accessory. This allows the carousel to be positioned accurately at either end of its 180˚ travel.

The controller can read the status of the four detector lines at the inspection station to determine the status of the order. Four outputs are used to test the conditions at the inspection station (two lines for shade of each ball and two lines for presence). If the condition matches the output, input 5 of the controller will be taken low.

SETTING UP THE ROTARY CAROUSEL and the INSPECTION STATION:

Remove the 3 screws that fasten the platter to the carousel. Removing the platter makes it easier to mount the unit to the table top.

Mount the base of the carousel to the workcell base with either 2 wood screws. Refer to the Rhino Workcell diagram for the relative placement of components.

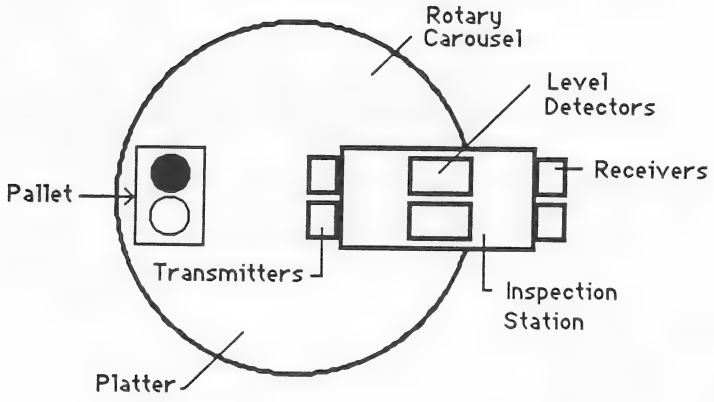


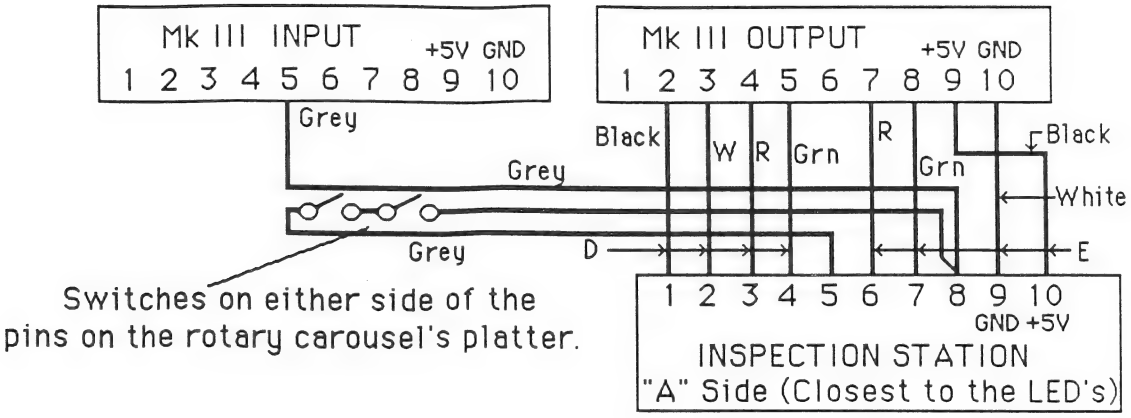
Figure 15
The Carousel and inspection station.

Remove the 4 screws holding the base plate to the bottom of the inspection station and set it aside. Mount the base to the workcell table top with 2 wood screws right behind the carousel again refering to the Rhino Workcell diagram. Re-attach the inspection station to its base.

Position the vertical axis of the carousel so that the home position microswitch is centered on the actuating cam. Replace the carousel's platter making sure the pins with the 2 switches on either side are positioned towards the Linear Slide Base and the other 2 pins are as close to the center of the Inspection Station as possible. You may have to loosen one of the clamps on the vertical axis shaft to allow proper orientation of the platter. Retighten the clamp. Be careful with the wires underneath the platter and make sure they are on the side closest to the Ball Feed Ramps.

Refer to the inspection station ("A" Side) Connection diagram and connect the inspection station to the Mark III Controller being sure all power is off.

Refer also to the inspection station ("B" Side) Connection diagram and ensure all connections are as they should be. (This section is shipped prewired.)



Controller Output 7 8
Inspection Station
("A" Side) Input 6 7

0 Accept Lamp On
1 Accept Lamp Off

0 Reject Lamp On
1 Reject Lamp Off

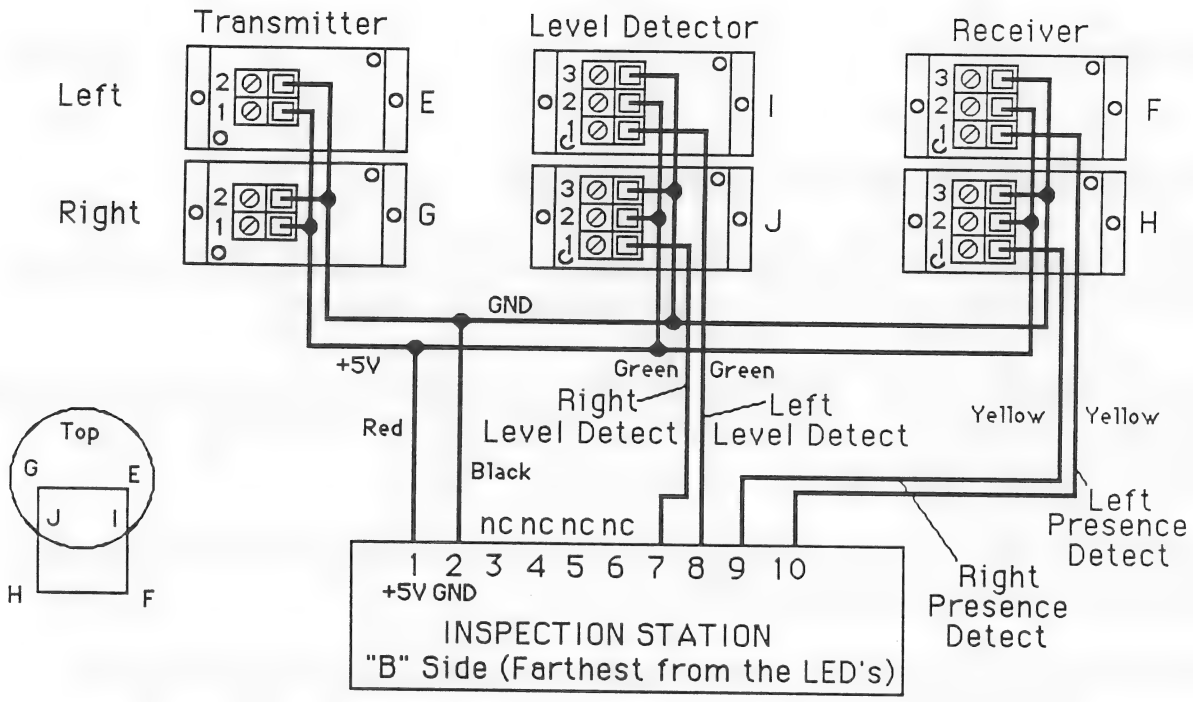
Controller Input 5 = 1
(Pallet on rotary carousel)
AND
(Controller outputs 2345=Inspection station inputs 78910)
OR
(No pallet is on the carousel platter)

Controller Input 5 = 0
(Pallet on rotary carousel)
AND
(Controller outputs 2345 <> Inspection stations inputs 78910)

Can set controller outputs 2345 to a state that cannot be matched by the inspection station and test if a pallet is seated correctly on the switches.
Note that input 5 is normally high due to an internal pull-up resistor when no circuit is attached.

Controller Outputs 2345 Inspection Station ("A" Side) Inputs 1234	Right Side	Left Side
0000	dark	dark
0001	dark	light
0010	light	dark
0011	light	light
0100	dark	---
0101	---	---
0110	light	---
0111	---	---
1000	---	dark
1001	---	light
1010	---	---
1011	---	---
1100	---	---
1101	---	---
1110	---	---
1111	---	---

Figure 16 INSPECTION STATION ("A" Side) CONNECTION



'Right' and 'Left' are referenced as seen <u>from</u> the robot.

78910	Right side	Left side	Notes
0000	dark	dark	
0001	dark	light	
0010	light	dark	
0011	light	light	
0100	dark	---	
0101	dark	---	bad left level or presence
0110	light	---	
0111	light	---	bad left level or presence
1000	---	dark	
1001	---	light	
1010	---	dark	bad right level or presence
1011	---	light	bad right level or presence
1100	---	---	
1101	---	---	bad left level or presence
1110	---	---	bad right level or presence
1111	---	---	both levels or presence's bad

Figure 17 INSPECTION STATION ("B" Side) CONNECTION

PRETESTING THE INSPECTION STATION:

With all power off, disconnect the wires leading to the Mark III Controller's outputs 7 and 8 and reconnect them to output 10 (Ground).

Turn the controller on. Both the Accept and Reject lamps on the Inspection Station should be lit. If either or both do not turn on, turn power off and recheck all connections.

If all else appears to be all right, the inspection station may be faulty and you should contact Customer Service.

Make sure all power is off and reconnect the wires to outputs 7 and 8.

Place a pallet onto the two pins of the platter underneath the Inspection Station.

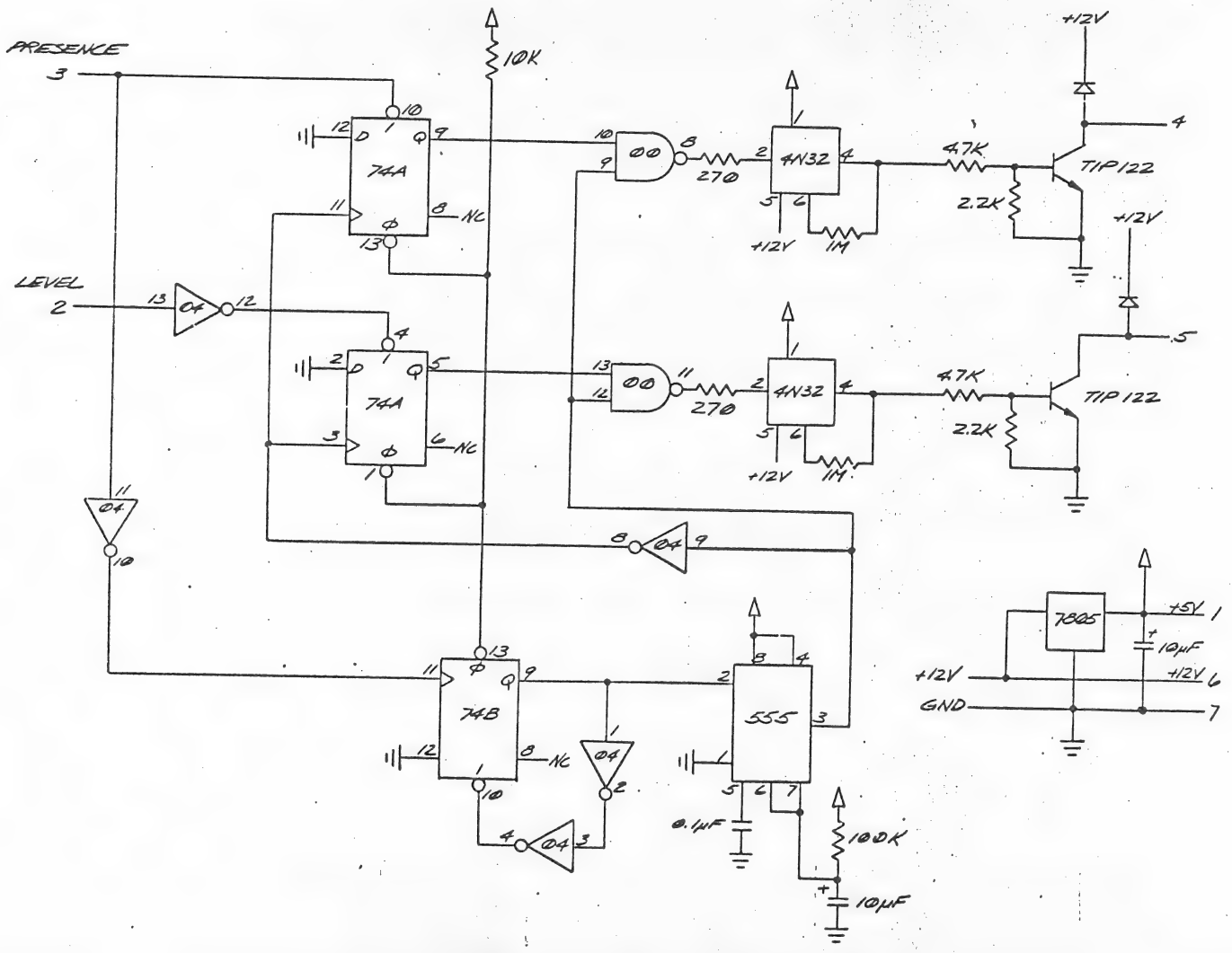
A voltmeter is required to measure the voltage on the pins on the inspection station ("B" Side) Connector.

Turn power on again.

With the voltmeter grounded to pin 2, pins 9 and 10 should give a voltage reading of between 3.5 and 5.0 volts.

Pins 7 and 8 should give a voltage reading of between 0 and 0.8 volts. If pin 9 shows a low voltage then Receiver "H" needs adjustment. If pin 10 shows a low voltage then Receiver "F" needs adjustment. If pin 7 shows a voltage too high then Level Detector "J" needs adjustment. If pin 8 shows a voltage too high then Level Detector "I" needs adjustment.

Refer to the Optic Modules description for the adjustment or calibration procedures.



REV.	DESCRIPTION	DATE	BY	APPROVED

RHINO ROBOTS, INC.
2505 S. NEIL ST.
CHAMPAIGN, IL 61820
(217) 352-8485

TITLE: WORK CELL 65
COLOR SORTER

DRAWN BY	CHECKED BY	SCALE	DATE
RJD	CAP		7-85

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DWG. NO. C30-130-1226

Place a ball of any color onto both sides of the pallet. Pins 9 and 10 should now show a voltage of 3.5 to 5.0 volts. With a dark ball on the right side of the pallet as seen from the robot, pin 7 should show a voltage of between 0 and 0.8 volts. A light ball should show a voltage of between 3.5 and 5.0 volts. Similary, a dark ball on the left side of the pallet should produce a voltage of 0 to 0.8 volts on pin 8 while a light ball should produce 3.5 to 5.0 volts.

Again, if your measured voltages differ from what is expected, refer to the Optic Modules description for calibration procedures. Be sure that the ping pong balls are well centered under the modules when making these readings. The color checker is more critical than the presence detector.

TESTING THE INSPECTION STATION:

Place a second pallet onto the pins of the platter of the carousel closest to the robot. Be sure the pallet is seated flat (both switches must close or the test will fail).

With a host computer attached to the Mark III Controller, boot up RoboTalk™ and run the program called "TSTINSPECT" ("tstinspe" on the IBM).

The monitor screen should first clear then display the current status of the inspection station.

As you place different combinations of light and dark or no balls on the pallet underneath the inspection station the screen should clear and display the current contents of the pallet.

If the screen continues to display an inspection station error then recheck the wire leading from pin 5 of the inspection station ("A" Side) through the 2 switches underneath the platter and terminating at input 5 of the controller.

Also check all wiring between the controller and the inspection station ("A" Side). If the same message still appears, remove the pallet closest to the

robot and manually press both switches down. If the message goes away, one or both switches need to be raised slightly. If the error message still persists, either the pretest procedure should be repeated or the inspection station may be faulty and you should contact Customer Service for service.

You should note that although a light ball appears light to the human eye, the optics module may sometimes recognize it as dark. The reverse is true for a dark ball. This usually happens due to reflections or surface irregularities and such a ball should be replaced or repainted.

THE VERTICAL CONVEYOR AND BALL SORTER

PURPOSE

The vertical conveyor and ball sorter provide a means of warehousing balls of two colors and then sorting the balls and providing the sorted balls at two fixed locations. This emulates a parts sorting and feeding system. The robot picks up the parts from known locations and puts back the parts at a known location.

CONTROL

The sorting of the balls is automatic. Whenever a ball appears in the sorter, it is either allowed to pass along the trough or dropped down to the lower trough depending on its color.

The vertical conveyor motor is controlled as an ON-OFF motor from port AUX 1 of the Mark III controller.

The controller can determine the presence of the **second ball** on each of the troughs.

MOUNTING THE VERTICAL CONVEYOR AND THE BALL SORTER

The vertical conveyor/sorter system is shipped as four separate parts assemblies that have to be assembled by the user. They are:

1. The conveyor itself
2. The sorting assembly and upper and lower troughs
3. The power supply and support column assembly
4. The ball return trough.

All the parts needed to assemble the unit into a working module are provided with the workcell.

The individual parts are prewired, and only the the wiring between them needs to be connected. The wiring from the optical module detectors to the Mark III Controller is discussed separately in other section of this manual.

Start by placing the vertical conveyor and ball chute in front of you on one side and the power column assembly on the other side. These two form the supports for the ball sorter and the ball return.

First mount the ball return to both the vertical elements. Do not tighten the screws at this time, you may need to make adjustments as you go along. This will space the vertical supports at the right distance from one another and will make it easier to install the ball sorter mechanism.

Next install the ball sorter mechanism parallel to the ball return on the two supports. Again do not tighten the screws just yet.

Next wire the power supply module to the sorter solenoids as indicated in the diagrams. This will make the sorting system complete.

Wire the detectors for the light and dark balls, at the end of the ball troughs, to the Mark III controller as shown in the diagrams. This completes the wiring of the vertical conveyor/sorter system.

After everything is together, tighten all screws.

Mount the unit on the worcell top with wood screws as shown.

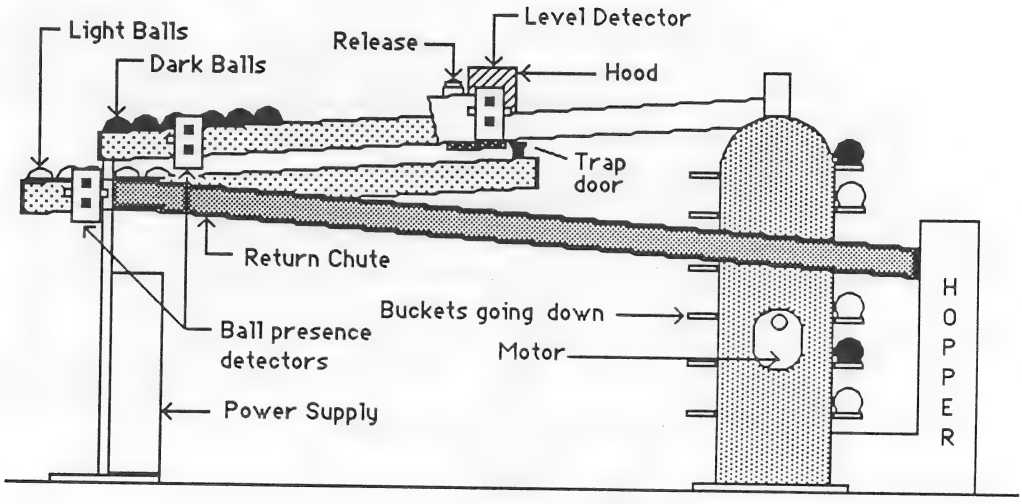


Figure 18
Vertical conveyor, ball ramps, sorter and return ramp mounting.

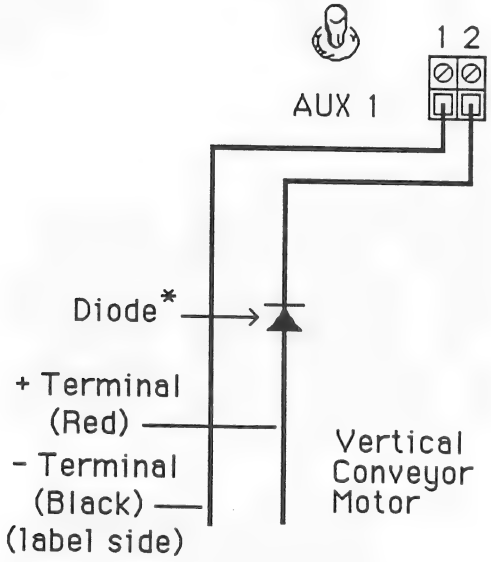
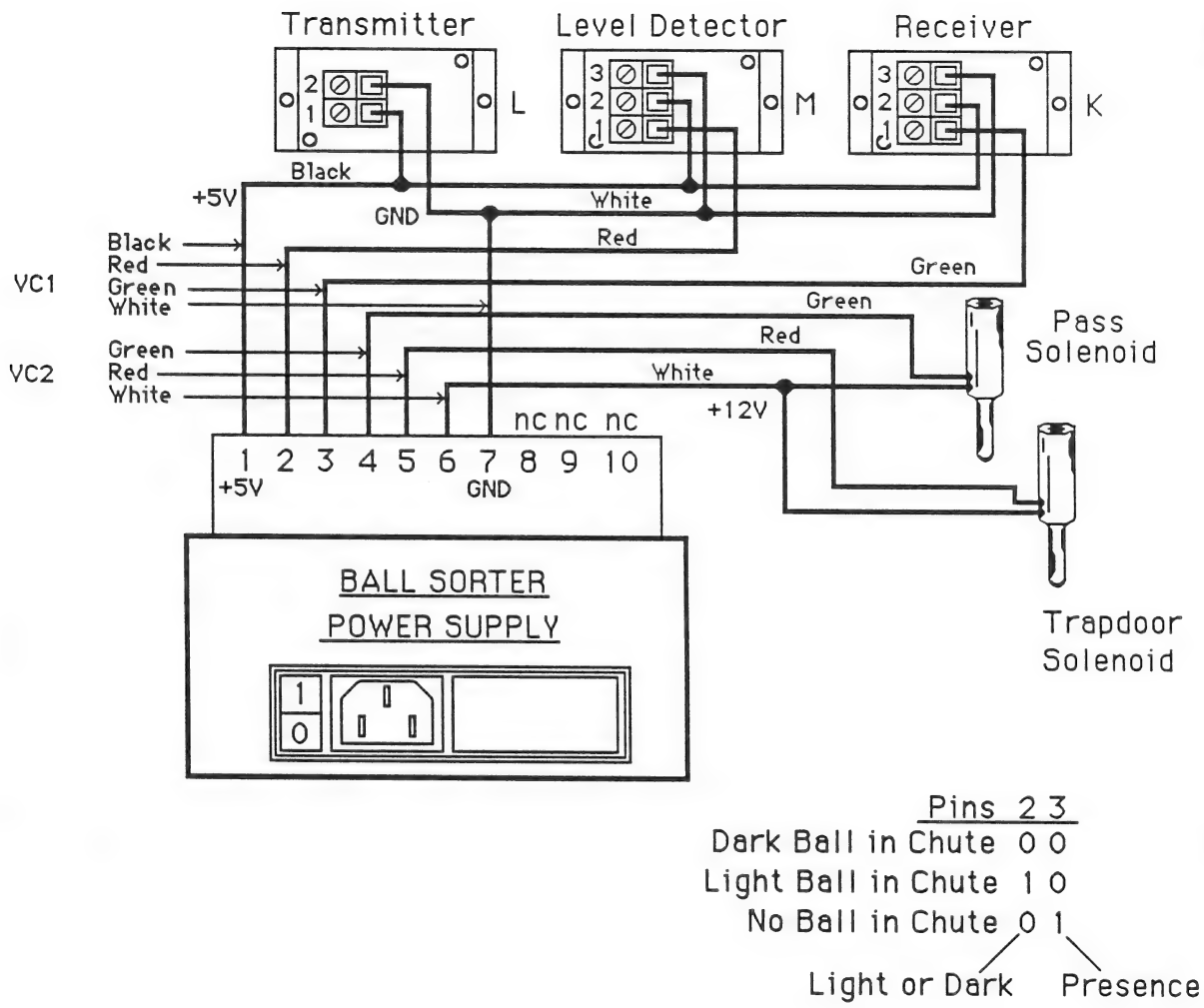
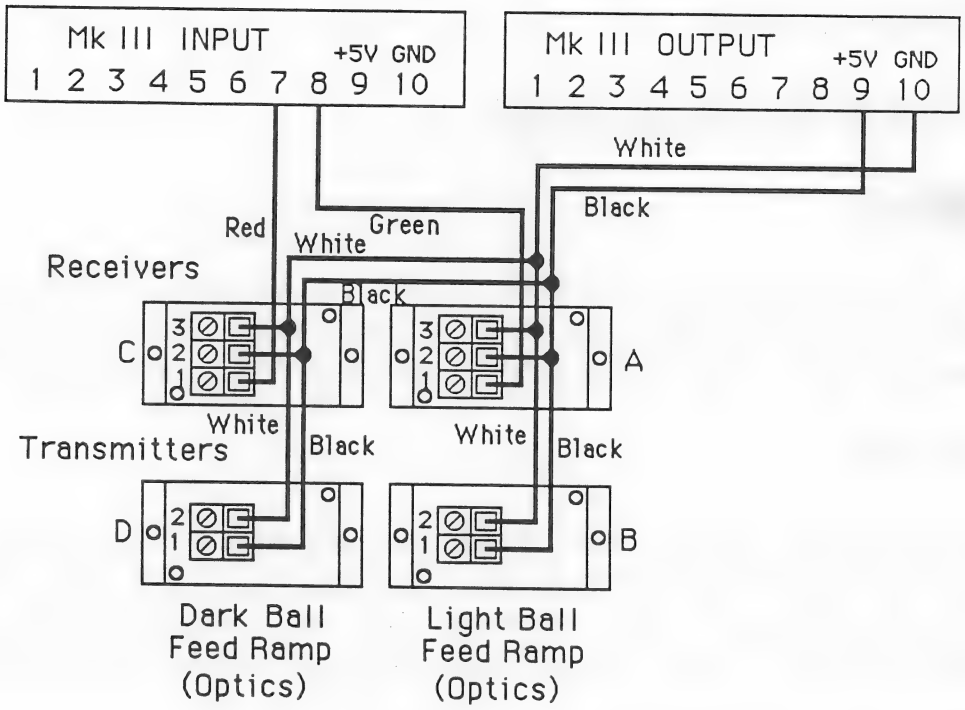


Figure 19
Vertical conveyor connections.



NOTE: BE SURE THE POWER SUPPLY IS ON BEFORE ATTEMPTING TO RUN THE VERTICAL CONVEYOR. FAILURE TO DO SO WHEN BALLS ARE IN THE SYSTEM MAY RESULT IN CRUSHING ONE OR MORE BALLS. (A quick way to turn off the conveyor is to flip the AUX 1 switch. This will turn off the conveyor due to a series diode used to prevent the conveyor from turning in the reverse direction.)

Figure 20 COLOR SORTER CONNECTION



BALL FEED DETECTOR CONNECTION

Inputs

7	0 = At least 2 dark balls
	1 = 1 or less dark balls
8	0 = At least 2 light balls
	1 = 1 or less light balls

Figure 21 BALL FEED DETECTOR CONNECTION

THE OPTIC MODULES

PURPOSE

The optic modules provide information to the controller on the presence and color of the ping pong balls in the system. The color testing is done with reflected light. The presence is detected by obstruction of an IR beam.

CONTROL

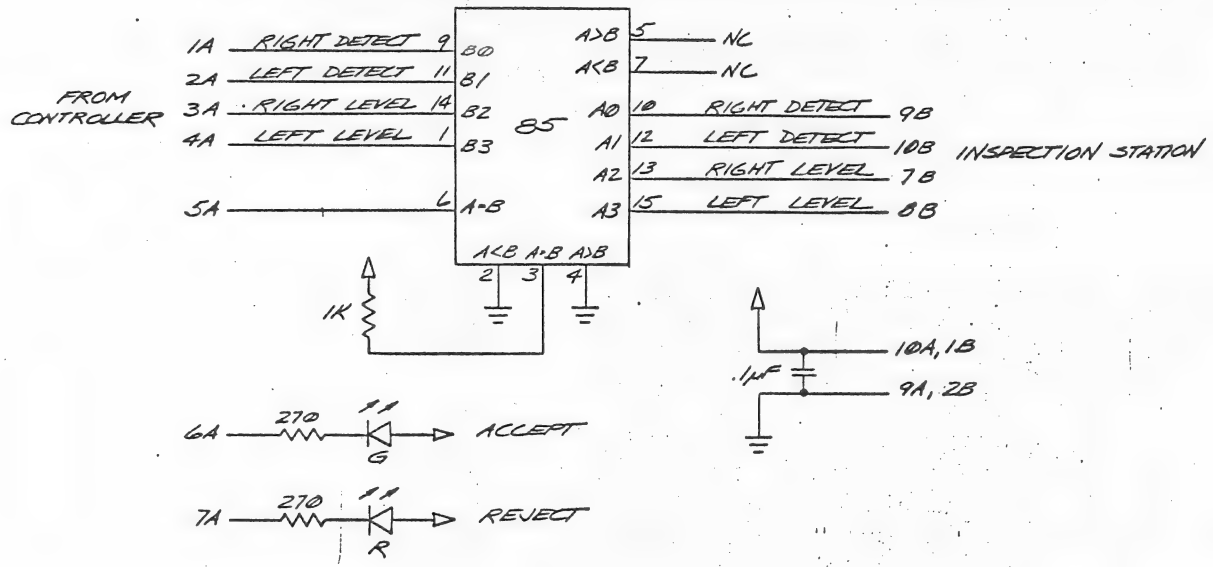
The controller can read the two types of detectors to determine wether the ball is present or not and if present whether the ball is dark or light. A ball that is not present is seen as a dark ball. The experimenter should determine that a ball is present before trying to determine its color.

THE OPTIC MODULES (detectors)

There are three types of optic modules, the Receiver, the Transmitter and the (Reflectance) Level Detector which is a combination of a Transmitter and a Receiver built into the same shell. The Receiver and Transmitter work together as a pair positioned across the object to be detected.

Transmitter: Referring to figure 21, the Transmitter has a two pin connector on top and an infra-red LED mounted inside such that it emits light through the middle hole on the bottom. (Note that the hole is off-center.) No adjustments are necessary, advisable or possible on the Transmitter modules.

Receiver: The Receiver has a three pin connector on top and a photo-transistor mounted inside it such that it receives light through the same middle hole on the bottom as the Transmitter. By mounting the Transmitter and Receiver such that they oppose each other, objects can be detected between them by the presence or absence of a signal at pin 3 on the Receiver (see figure 21). Shading the sensor is not necessary as the optic module housing itself provides for it. It may be necessary to adjust the



REV.	DESCRIPTION	DATE	BY	APPROVED

RHINO ROBOTS, INC.
2505 S. NEIL ST.
CHAMPAIGN, IL 61820
(217) 352-8488

TITLE: INSPECTION STATION SCHEMATIC

DRAWN BY	CHECKED BY	SCALE	DATE
RJD	CAP		7-85

DO NOT SCALE DRAWING

DWG. NO. 1239

trim pot located behind a hole in the side of the optic module. A small screwdriver is required. With no object between the modules a voltage of 3.5 to 5.0 volts should be read at the signal pin (pin 1) of the Receiver. With an object blocking the light from the Transmitter, a voltage of 0.0 to 0.8 volts should be read at the signal pin of the Receiver.

To calibrate the Receiver, mount the Transmitter and Receiver as shown in figure 21 with no obstacles between them. With a voltage meter at the signal pin of the Receiver, adjust the trim pot with the screwdriver until a high voltage is obtained then back off until the voltage drops to a low then turn the trim pot in the other direction again until the high voltage just returns. If you change the distance between the modules you may find it necessary to readjust the Receiver sensitivity.

Level Detector: The Level Detector is essentially a Transmitter and Receiver pair built into one module. However the infra-red LED and phototransistor are mounted at an angle (see figure 22). This allows you to detect the difference between light and dark objects based on their reflective properties of infra-red light. The infra-red LED is mounted in the left hole in the bottom of the module (near the middle) and the phototransistor is mounted in the hole nearest the end of the module.

Like the Receiver, a trim pot is located inside the hole on the side of the module and may require adjustment. In this case, with no object or a very dark object the voltage at the signal pin (pin 1) should be 0.0 to 0.8 volts. With a light or highly reflective object a voltage of 3.5 to 5.0 volts should be read. The adjustment procedure is the same as for the Receiver but with a light or highly reflective object in place.

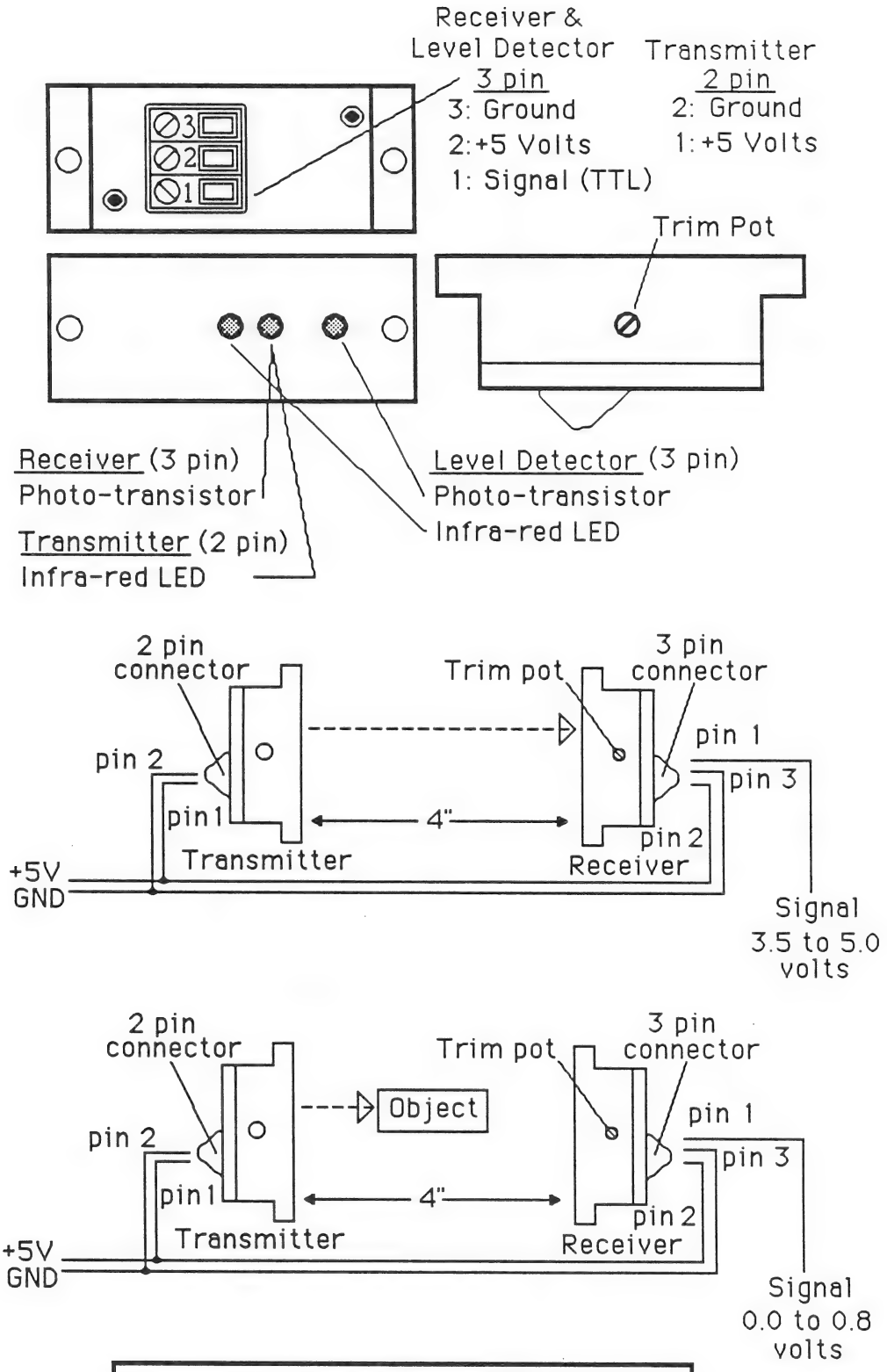
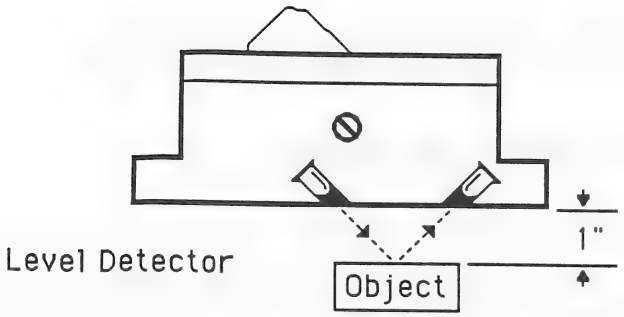
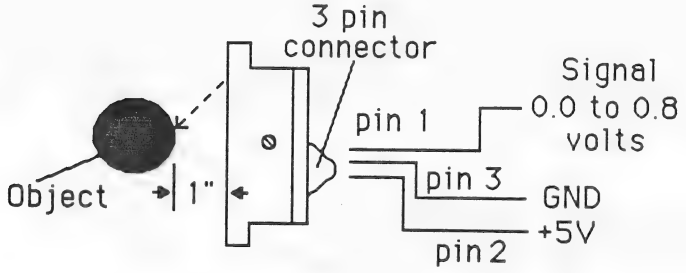
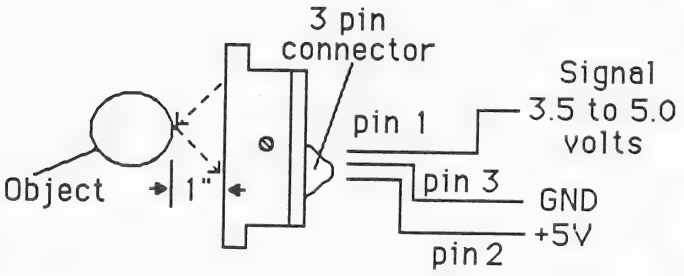


Figure 22 Optic Module Adjustments





Low Level Detection



High Level Detection

Figure 23 Optic Modules

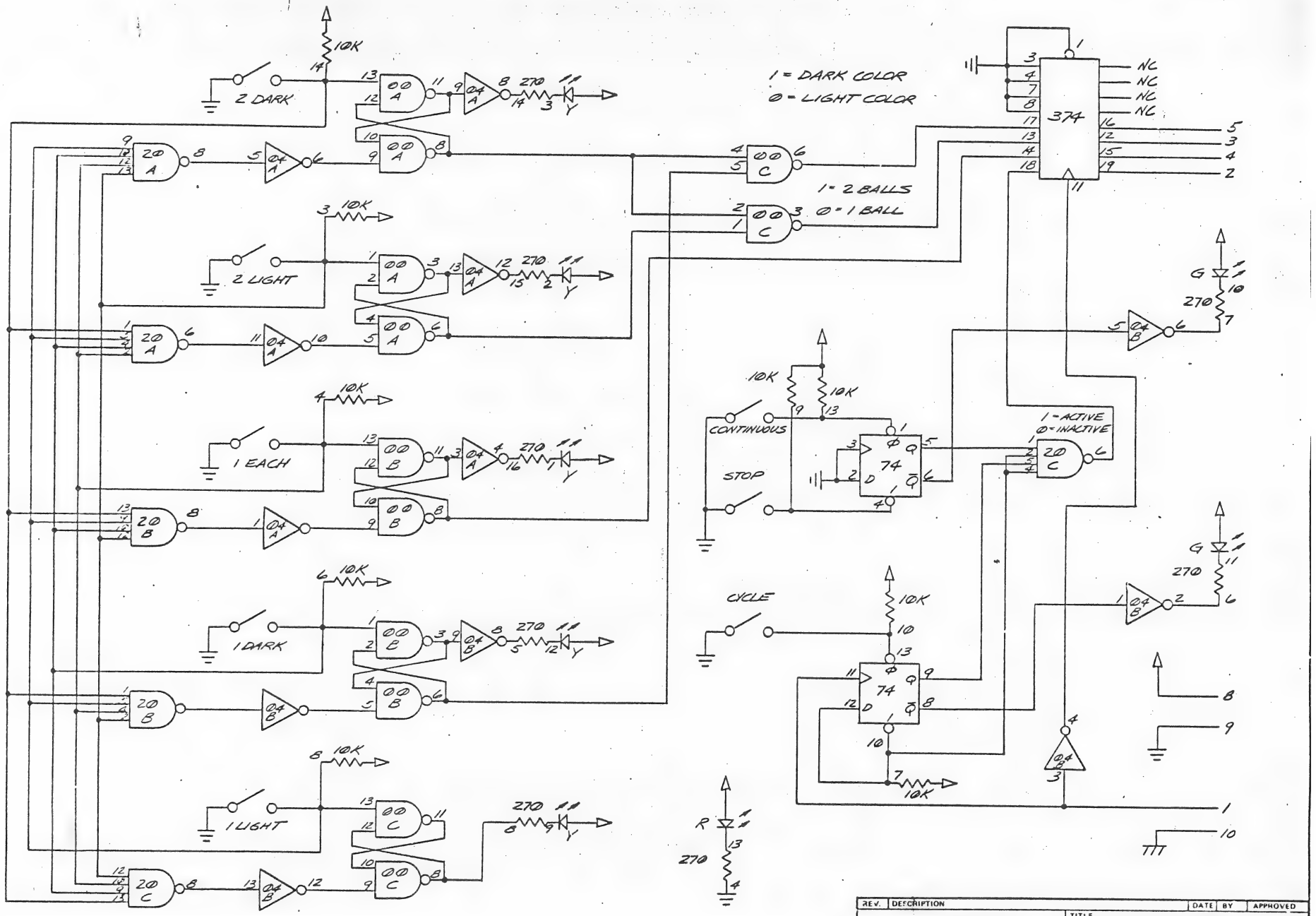
TEACHING THE POINT LOCATIONS

NEED TO REDEFINE POINT LOCATIONS

The programs provided with the workcell use named locations as points that the robot moves to. These were defined at the factory for the particular workcell that the software was developed on. Your workcell will be slightly different from the one at the factory because your components will be mounted slightly differently on your workcell. For this reason it is necessary for you to redefine the points in the workcell as the points that are specific for your particular workcell. The locations of the points are defined in the attached figures.

TEACHING THE XR-2 WORKCELL LOCATION POINTS UNDER RoboTalk™

In a workcell environment, a robot may be required to approach an object, grip it and retreat while avoiding obstacles that are many times very close to the object of interest. A programmer/user must be very careful in manipulating the robot around these obstacles to avoid damaging either the obstacle or the robot arm/gripper itself. Usually, in teaching the arm, whether it be by lead-through or teach pendant, avoiding the obstacles is relatively easy. The problem arises when the program is run. In point-to-point robot systems, be they straight-line path or not, the robot will **not** follow the exact path that was taken when the robot was taught. It is only the points in space themselves that were taught and not the path and so the arm doesn't really care how it gets to the point. Figure 23 illustrates a typical problem. The left illustration shows the path that was taken in teaching the robot. Although the motors may start at the same time, because one axis may have farther to travel than another, the axis do not stop at the same time and the path shown by the right illustration of figure 23 is taken resulting in a collision.



REV.	DESCRIPTION	DATE	BY	APPROVED

RHINO ROBOTS, INC.
2505 S. NEIL ST.
CHAMPAIGN, IL 61820
(217) 352-8485

TITLE: ORDER CENTER VER 2.0
WORK CELL 85

DRAWN BY	CHECKED BY	SCALE	DATE
RJD	DAP		7-85

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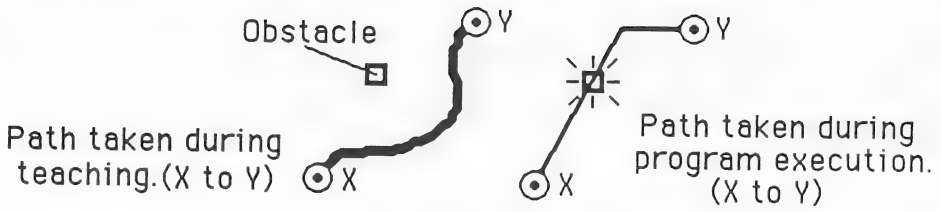


Figure 24
Relative robot arm paths.

Normally this problem is only of interest when picking up or putting down an object. The easiest way around the problem is to limit the number of axes that would be running when approaching or retreating from critical points. Figures 24 and 25 illustrate this. In both cases, only the the D motor joint is being operated between points P1 and P2. In this way the programmer/user can see exactly the path the robot will take and therefore not fear a mishap when the robot executes the taught program. In general, when using Robotalk, the procedure to follow is:

1. Move the robot such that the gripper is in position to grip or release the object of interest. (P1).

2. Move a single axis (usually the D axis works best) such that the gripper moves away from the previously taught point. (P2). This point is then the point the robot will move to prior to moving to P1 and is also the point the robot will move to when moving away from P1.

For example, assume that a square block is at location P1 and we are interested in picking it up to transfer it to some other place.

1. Using the pendant (after entering 'T P1' in edit mode), move the robot to P1 with the gripper open and ENTER that as a point. Then enter 'T P2' and move the D axis to bring the gripper to P2 and

ENTER that as a point. Finally, enter 'T P3', close the gripper and ENTER that as a point. Note that P3 and P2 are the same points in space with the difference being the gripper is open at P2 and closed at P3.

The executable program would then look like this:

```
movep P2   ;gripper open, ready to approach the object
movep P1   ;gripper open, ready to grasp the object
close -1   ;grasp the object, ready to move away from the object
movep P3   ;gripper closed, ready to move to some other place
```

2. It should be noted that since P3 was taught with the gripper closed, and, since the gripper is always operated first before any other axis is operated, the command 'close -1' is redundant and can be left out.

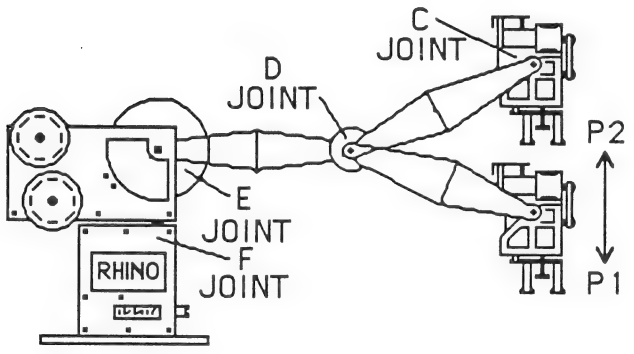


Figure 25
Effect of moving the elbow joint only.

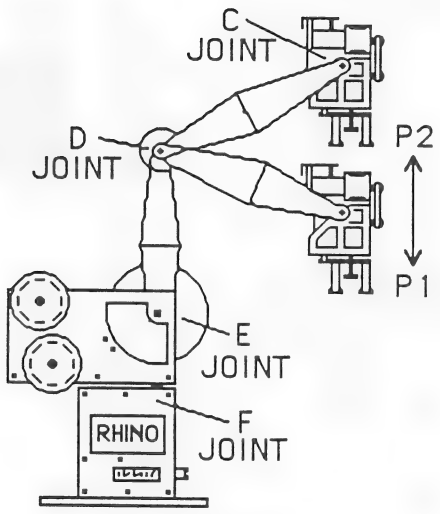
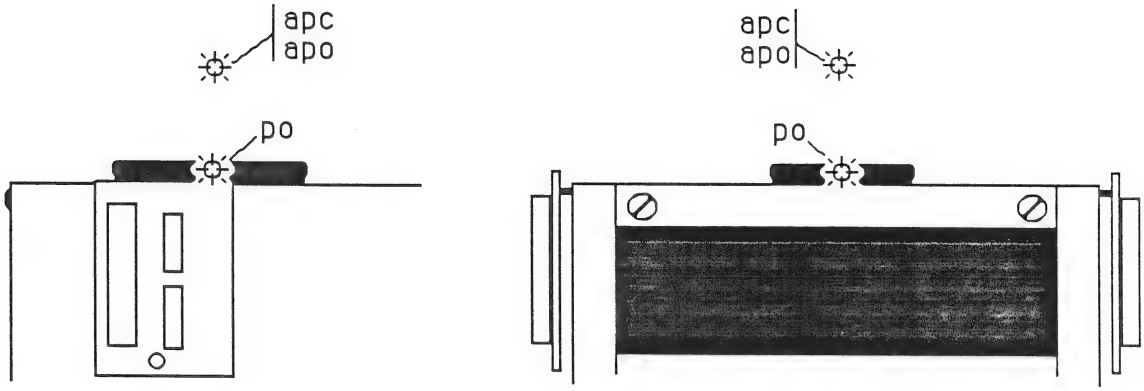
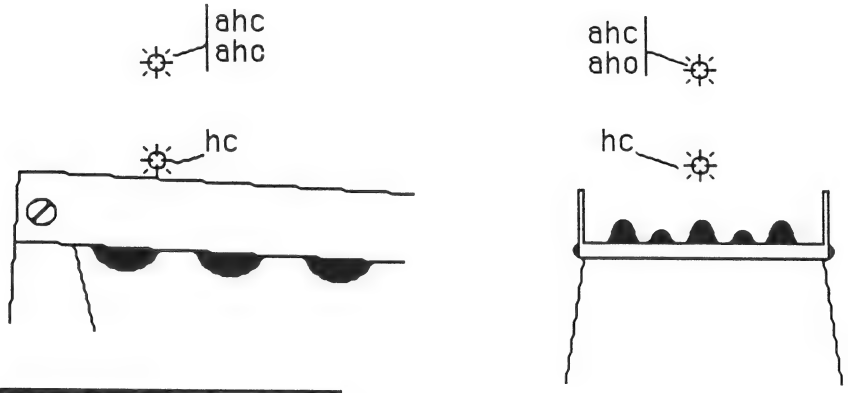


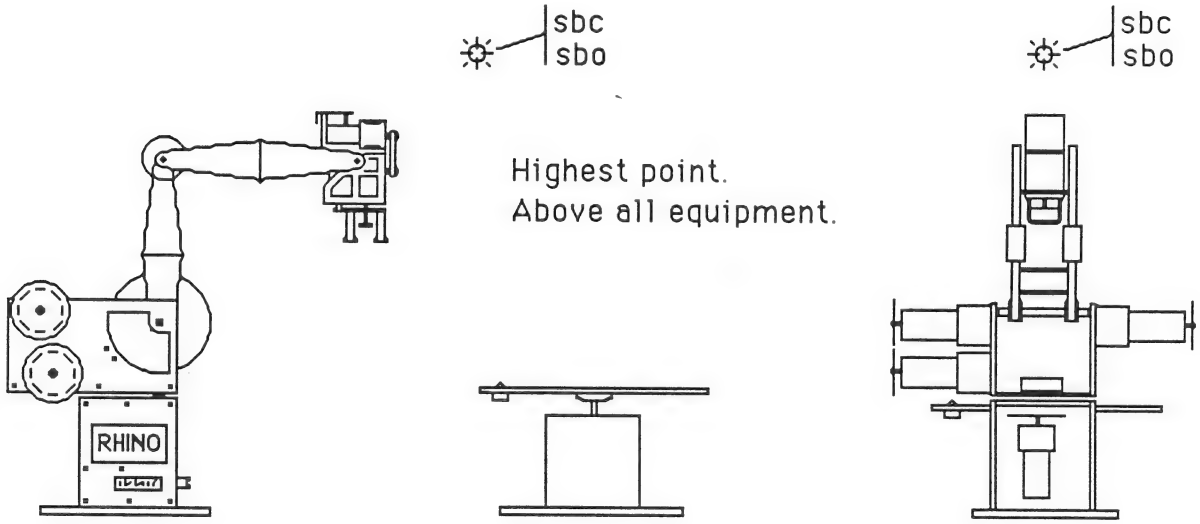
Figure 26
Effect of moving the Elbow joint only.



Pallet feed points.



Pallet return points.

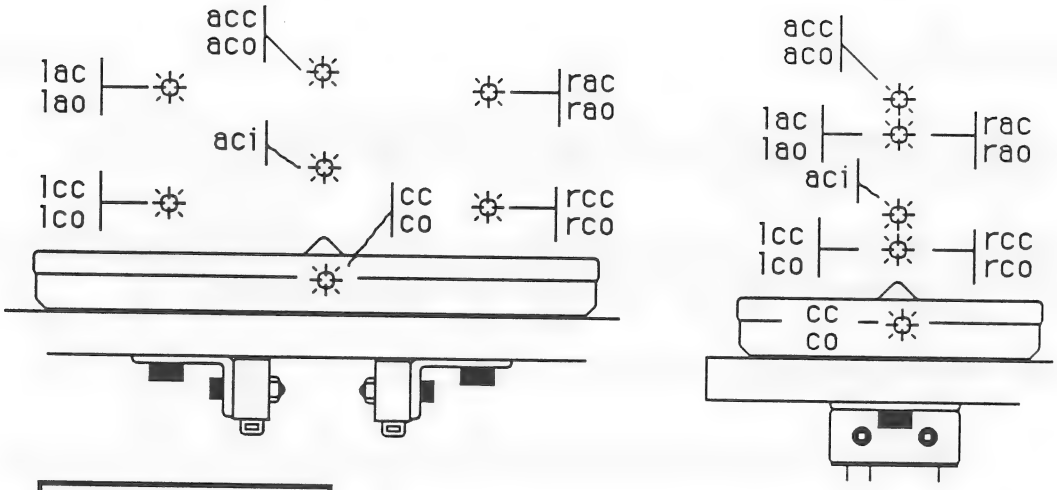


Highest point.
Above all equipment.

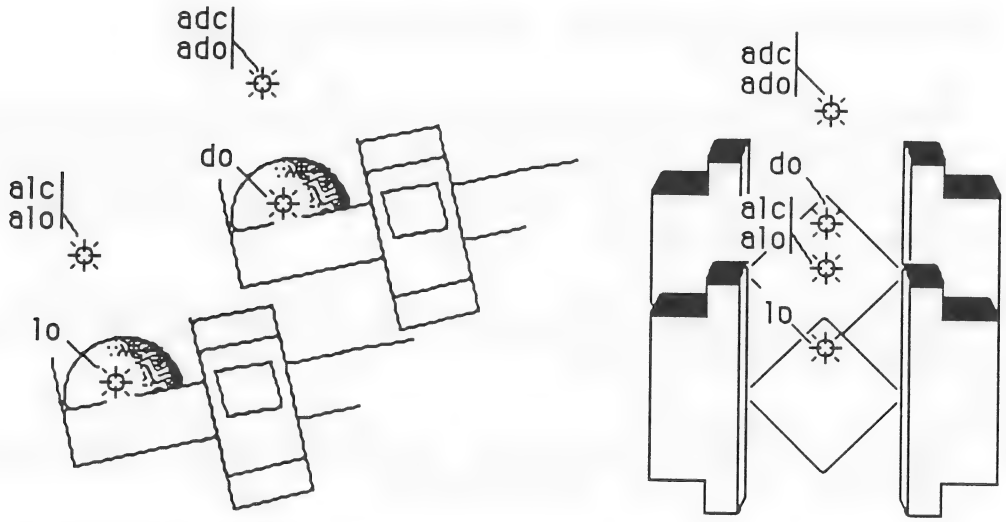
Figure 27

Safe position points.

WC point2



Carousel points.



Ball feed points.

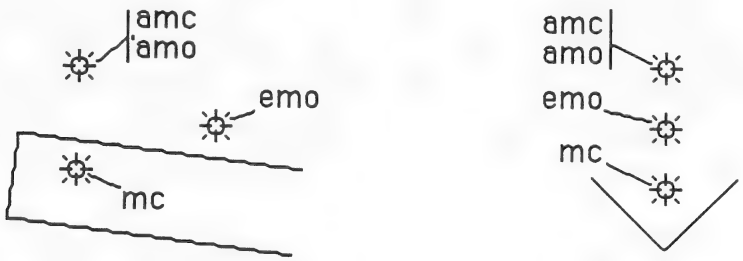


Figure 28

Ball return ramp points.

WC point1

RHINO WORKCELL STARTUP PROCEDURE

Once the workcell has been assembled and tested, the system is ready to be used. The following startup procedure is recommended.

1. Make sure all power switches are off.

2. Make sure the host computer (Apple IIe, IBM PC) is plugged in.

3. Make sure the Mark III Controller is plugged in.

4. Make sure the Ball Sorter Mechanism is plugged in.

5. Turn on the Ball Sorter Mechanism. Throw a ball or two into the sorter and make sure the Ball Sorter works. (If a ball bucket is in the way, you can move it away by turning the shaft on the vertical conveyor motor with your hand.)

6. Be sure the mode switch on the Mark III Controller, is in the "UP" or teach pendant position.

7. Turn on the Mark III Controller. The XR-2 gripper should close then open. If it doesn't, press RESET.

8. If you have an IBM-PC as the host, skip to step 10. There are two sets of black pins on the platter of the rotary carousel. One set has a small switch on either side. This set of pins is supposed to be nearest the robot arm. The other set should be centered under the inspection station. The best way to do this is to place a pallet on the pins under the inspection station and center the carousel using the teach pendant's "H" motor keys.

NOTE: Be sure not to turn the carousel in a direction that will cause the wire under the carousel's platter to wind around itself. Accuracy is not critical but if you wish you can use tape or a

mark on the platter and inspection station to aid in centering.

9. Using the pendant's "G" motor keys, center the spike that's on the base of the robot on the mark on the yellow tag located on the work base under the front of the linear slide base.

10. Using the pendant, execute a "Hard Home"

11. After the hard home has been executed, turn on the host computer and boot up RoboTalk™.

12. Answer "yes" when queried about initializing the robot.

13. If you have an IBM-PC as your host computer, load the "HOMEGH" program and execute it. This will home the linear slide base and the rotary carousel.

14. Load "WORKI" if the host is an IBM-PC. Load "WORKA" if the host is an Apple IIe.

15. Enter the direct exectution mode and do a HARDHOME. Then return to the main RoboTalk Menu.

16. You are now ready to either run a workcell program provided by Rhino or to create and run your own programs.

The workcell can also be programmed in the other robotic language emulations provided by Rhino.

USING THE WORK CELL.

The work cell may be used in the following modes:

--> As a demonstration work cell used primarily as a demonstration device to familiarize potential users with the type of functions that a robotic work cell can be expected to perform.

--> As a training tool to train personnel in the use of robotic languages. Learning to use the language is facilitated when there is a specific task at hand. The students learn by programming the robot to execute the functions needed to make the work cell do its work.

--> As a training tool for use in learning about the hardware needs of robotic cells as related to the capability of each device in the work cell and the need of input and output lines to allow the entire system to be tied together.

--> The work cell may also be reconfigured to show the students that there are many ways to set up a work cell for any single task.

CONTROLLING THE WORK CELL.
THE COMMANDS THAT YOUR WORK CELL OBEYS.

It is easiest to control the work cell from a higher level language such as RoboTalk™. The RoboTalk language is provided as a part of the controller package on all new Mark III Controllers. It is available for all older Mark III and Mark II controllers with teach pendants. The ROM in the pendant has to be changed to a version 2.3 or later. Versions for the IBM-PC and the Apple IIe only are supported. It is also possible for sophisticated users to write their own languages or routines to control the robot and the work cell.

In general the motors and the I/O on the robot and the work cell may be

controlled in the following ways.

--> From any general purpose computer by using the kernel commands that the controller understands. This allows full control of the Mark III controller in machine language. It can give extremely fast and sophisticated operation but needs a more sophisticated understanding of computers and software to implement. See owner's manual for the Rhino XR Series robots.

--> From any of the languages provided by Rhino Robots Inc., such as RoboTalk™ and Rhino-VAL. All of these languages have commands that address the "G" and the "H" ports. See the appropriate software manual for these commands.

--> The teach pendant. The teach pendant can provide control either as a stand alone device or within the context of a language. The languages provided by Rhino support the use of the teach pendant to define the points accessed by the robot.

ADVANCED USAGE.

Introduction: A work cell is the normal operating environment of a robot. All the machines that serve and are served by the robot are a part of the robot's work cell. The workcell is designed as a teaching aid for students and trainees. It has all the components of a full sized industrial workcell. The software that is controlling the workcell is written in a new robotic language called RoboTalk™. RoboTalk is a generic robotic language that is similar to all industrial robotic control languages. RoboTalk was developed by Rhino Robots Inc. for use as a teaching and training language that is easy to use. RoboTalk contains a number of features like an extensive trace capability that make it the ideal language for the first time robot user.

RoboTalk™

RoboTalk is a full fledged robot control language. It is available for use on the IBM-PC, the IBM-PCXT and the Apple IIe. The language is written in "C" and then compiled to run on the target processors. The language cannot be modified by the user. RoboTalk supports integer math. RoboTalk has 29 commands and a full fledged single line editor similar to the Unimation VAL™ editor. RoboTalk is the ideal first language for all individuals interested in learning about robots and robotic languages. The entire system is under the control of an IBM-PC personal computer running a RoboTalk program.

RoboTalk is a new robotic language developed by Rhino Robots Inc for the educational and training market. RoboTalk is a generic introduction to all robotic languages.

TRADEMARKS

APPENDICES

Rhino supports the Apple IIe and the IBM-PC as host computers for the Rhino XR Experimental Robot system. The following pages contain hardcopy printouts of RoboTalk™ programs for both systems. These programs are also provided on the diskettes provided with the workcell.

The following RoboTalk™ programs are provided for the IBM-PC:

1.	tstfeed	Ball feeder test program
2.	tstorder	Order center test program
3.	tstinspe	Inspection station test program
4.	worki	Workcell run program
5.	workdoc	Documentation only for the workcell program. This program cannot be run.

The following RoboTalk™ programs are provided for the Apple IIe:

1.	tstfeed	Ball feeder test program (program list'g same as IBM)
2.	tstorder	Order center test program (program list'g same as IBM)
3.	tstinspect	Inspection station test program (program list'g same as IBM)
4.	worka	Workcell run program
5.	workda	Documentation only for the workcell program. This program cannot be run.

```
em
rem file: TSTORDER   Order center test routine.
rem
rem Shows any changes to current order on screen.
rem
outsig -1
seti a=2
seti b=t
5 outsig -1
outsig 1
seti s=0
ifsig -1 then goto 31
seti t=0
ifsig -2 then goto 32
ifsig 4 then goto 33
seti t=t+2
33 ifsig 3 then goto 34
seti t=t+1
goto 32
34 seti t=t+2
32 seti s=1
31 if s < a then goto 40
if s > a then goto 40
if t=b then goto 5
40 seti b=t
seti a=s
cls
if s=0 then goto 50
type ""
type "A new selection has been made."
type ""
type "The order placed is:"
type ""
if t=0 then type "1 of each"
if t=1 then type "1 dark ball"
if t=2 then type "2 dark balls"
if t=3 then type "1 light ball"
if t=4 then type "2 light balls"
goto 5
50 type ""
type "No selection has been made."
goto 5
end
rem
rem
rem    outsig -1                    ;reset order data latch line
rem    seti a=2                     ;initialize copy of selection flag
rem    seti b=t                     ;initialize copy of type flag
rem 5  outsig -1                    ;reset order data latch line
rem    outsig 1                     ;latch order center data
rem    seti s=0                     ;initialize selection flag=no selection
rem    ifsig -1 then goto 31        ;branch if no selection made
rem    seti t=0                     ;initialize type flag=1 of each
rem    ifsig -2 then goto 32        ;branch if type=1 of each
rem    ifsig 4 then goto 33         ;branch if dark ball(s)
rem    seti t=t+2                   ;light ball so offset t
rem 33 ifsig 3 then goto 34         ;branch if 2 balls
rem    seti t=t+1                   ;one ball so offset t
rem    goto 32
rem 34 seti t=t+2
rem 32 seti s=1                     ;a selection has been made
```

```
rem 31 if s<a then goto 40
rem    if s>a then goto 40          ;branch if s changes
rem    if t=b then goto 5           ;branch if s,t didn't change
rem 40 seti b=t                     ;copy t
rem    seti a=s                     ;copy s
rem    cls
rem    if s=0 then goto 50          ;branch if no selection made
rem    type ""
rem    type "A new selection has been made."
rem    type ""
rem    type "The order placed is:"
rem    type ""
rem    if t=0 then type "1 of each"
rem    if t=1 then type "1 dark ball"
rem    if t=2 then type "2 dark balls"
rem    if t=3 then type "1 light ball"
rem    if t=4 then type "2 light balls"
rem    goto 5
rem 50 type ""
rem    type "No selection has been made."
rem    goto 5
rem    end
```

```
rem
rem file: ISTINSPECT    Program to test inspection station optics
rem                     and carousel pallet detection switches.
rem
5 seti a=10
10 outsig -2
 outsig -3
outsig 4
outsig -5
ifsig 5 then goto 30
seti x=0
outsig 2
outsig 3
outsig 4
outsig 5
ifsig 5 then goto 20
seti x=1
outsig -4
ifsig 5 then goto 20
seti x=2
outsig -5
ifsig 5 then goto 20
seti x=3
outsig 4
ifsig 5 then goto 20
seti x=4
outsig -2
ifsig 5 then goto 20
seti x=5
outsig 3
ifsig 5 then goto 20
seti x=6
outsig -3
ifsig 5 then goto 20
seti x=7
outsig 2
ifsig 5 then goto 20
seti x=8
outsig -4
ifsig 5 then goto 20
seti x=9
20 if a=x then goto 10
cls
type ""
if x=0 then type "Order being tested is: 2 dark balls"
if x=1 then type "Order being tested is: 1 of each, reversed"
if x=2 then type "Order being tested is: 2 light balls"
if x=3 then type "Order being tested is: 1 of each"
if x=4 then type "Order being tested is: 1 light ball"
if x=5 then type "order being tested is: 1 dark ball, reversed"
if x=6 then type "Order being tested is: none"
if x=7 then type "Order being tested is: 1 dark ball"
if x=8 then type "Order being tested is: 1 light ball, reversed"
if x=9 then type "Inspection station error"
seti a=x
goto 10
30 cls
type ""
type "A pallet must be seated correctly on the carousel."
35 outsig -2
outsig -3
```

```
outsig 4
outsig -5
ifsig 5 then goto 35
seti a=10
goto 5
end
rem
outsig -2
outsig -3
outsig 4
outsig -5
ifsig 5 then goto 30
rem
rem 5  seti a=10                    ;initialize copy of x
rem 10 outsig -2                    ;check if pallet seated
rem    outsig -3
rem    outsig 4
rem    outsig -5
rem    ifsig 5 then goto 30         ;branch if pallet not there
rem    seti x=0                     ;initialize x
rem    outsig 2                     ;check for 2 dark balls
rem    outsig 3
rem    outsig 4
rem    outsig 5
rem    ifsig 5 then goto 20         ;branch if 2 dark balls
rem    seti x=1
rem    outsig -4
rem    ifsig 5 then goto 20         ;branch if 1 of each, reversed
rem    seti x=2
rem    outsig -5
rem    ifsig 5 then goto 20         ;branch if 2 light balls
rem    seti x=3
rem    outsig 4
rem    ifsig 5 then goto 20         ;branch if 1 of each
rem    seti x=4
rem    outsig -2
rem    ifsig 5 then goto 20         ;branch if 1 light ball
rem    seti x=5
rem    outsig 5
rem    ifsig 5 then goto 20         ;branch if 1 dark ball, reversed
rem    seti x=6
rem    outsig -3
rem    ifsig 5 then goto 20         ;branch if none
rem    seti x=7
rem    outsig 2
rem    ifsig 5 then goto 20         ;branch if 1 dark ball
rem    seti x=8
rem    outsig -4
rem    ifsig 5 then goto 20         ;branch if 1 light ball, reversed
rem    seti x=9                     ;no match so error
rem 20 if a=x then goto 10          ;branch if no change since last time
rem    cls
rem    type ""                      ;update screen
rem    if x=0 then type ...
rem    if x=1 then type ...
rem    if x=2 then type ...
rem    if x=3 then type ...
rem    if x=4 then type ...
rem    if x=5 then type ...
rem    if x=6 then type ...
rem    if x=7 then type ...
rem    if x=8 then type ...
rem    if x=9 then type ...
rem    seti a=x                        ;reset copy of x
rem    goto 10
rem 30 cls
```

```
rem     type ""
rem     type "A pallet must be seated correctly on the carousel."
rem 35  outsig -2                                   ;make sure it s seated
rem     outsig -3
rem     outsig 4
rem     outsig -5
rem     ifsig 5 then goto 35
rem     seti a=10
rem     goto 5
rem     end
rem
```

```
rem
rem file: WORK1  workcell program for the IBM PC.
rem
rem See WORKDOC.1,2,3 for documented version.
rem
outsig -1
outsig 1
outsig -1
cls
movep 500
20 set1 n=0
cls
type ""
type "Place your order."
20 outsig -1
outsig -7
outsig -8
gosub 30
if s=0 then goto 20
set1 n=n+1
cls
type ""
type "Executing order cycle number:"
type n
type ""
type "Order placed is:"
type ""
if t=0 then goto 21
if t=1 then goto 22
if t=2 then goto 23
if t=3 then goto 24
goto 25
21 type "1 of each"
type ""
gosub 90
gosub 48
gosub 47
gosub 60
gosub 75
gosub 74
gosub 91
goto 20
22 type "1 dark ball"
 type ""
gosub 90
gosub 48
gosub 60
gosub 74
gosub 91
goto 20
23 type "2 dark balls"
type ""
gosub 90
gosub 48
gosub 49
gosub 60
gosub 75
gosub 74
gosub 91
goto 20
24 type "1 light ball"
```

```
type ""
gosub 90
gosub 47
gosub 60
gosub 75
gosub 91
goto 20
25 type "2 light balls"
type ""
gosub 90
gosub 46
gosub 47
gosub 60
gosub 75
gosub 74
gosub 91
goto 20
60 movep is
gosub 40
if t=0 then goto 61
if t=1 then goto 62
if t=2 then goto 63
if t=3 then goto 64
goto 65
61 if x=3 then goto 89
gosub 88
if x=0 then goto 108
if x=1 then goto 125
if x=2 then goto 109
if x=4 then goto 106
if x=5 then goto 124
if x=6 then goto 128
if x=7 then goto 105
if x=8 then goto 129
goto 200
62 if x=7 then goto 89
gosub 88
if x=0 then goto 101
if x=1 then goto 115
if x=2 then goto 121
if x=3 then goto 101
if x=4 then goto 123
if x=5 then goto 102
if x=6 then goto 106
if x=8 then goto 109
goto 200
63 if x=0 then goto 89
gosub 88
if x=1 then goto 109
if x=2 then goto 112
if x=3 then goto 122
if x=4 then goto 111
if x=5 then goto 106
if x=6 then goto 110
if x=7 then goto 107
if x=8 then goto 113
goto 200
64 if x=4 then goto 89
gosub 88
if x=0 then goto 120
if x=1 then goto 116
if x=2 then goto 100
if x=3 then goto 100
if x=5 then goto 108
if x=6 then goto 105
if x=7 then goto 126
```

```
    goto 200
    65 if x=2 then goto 89
    gosub 88
    if x=0 then goto 118
    if x=1 then goto 108
    if x=3 then goto 114
    if x=4 then goto 104
    if x=5 then goto 119
    if x=6 then goto 117
    if x=7 then goto 127
    if x=8 then goto 105
    goto 200
    89 outsig 7
    outsig -8
    type "Order is ACCEPTED"
    movep sbo
    return
    88 outsig 8
    outsig -7
    type "Order is REJECTED"
    movep sbo
    return
    200 type ""
    type "Inspection station malfunctioning."
    type "Check it and restart the program."
    end
    100 gosub 74
    goto 60
    101 gosub 75
    goto 60
    115 gosub 74
    102 gosub 76
    goto 60
    116 gosub 75
    103 gosub 77
    goto 60
    114 gosub 74
    104 gosub 46
    goto 60
    120 gosub 74
    108 gosub 75
    105 gosub 47
    goto 60
    121 gosub 75
    109 gosub 74
    106 gosub 48
    goto 60
    112 gosub 74
    111 gosub 75
    110 gosub 48
    107 gosub 49
    goto 60
    113 gosub 74
    goto 110
    118 gosub 74
    119 gosub 75
    117 gosub 46
    goto 105
    122 gosub 75
    goto 107
    123 gosub 75
    goto 106
    125 gosub 74
    124 gosub 76
    goto 105
```

```
126 gosub 74
goto 105
127 gosub 74
goto 117
128 gosub 48
goto 105
129 gosub 77
goto 106
40 seti x=0
outsig 2
outsig 3
outsig 4
outsig 5
ifsig -5 then goto 1
type "Actual order is: 2 dark balls"
return
1 seti x=1
outsig -4
ifsig -5 then goto 2
type "Actual order is: 1 of each, reversed"
return
2 seti x=2
outsig -5
ifsig -5 then goto 3
type "Actual order is: 2 light balls"
return
3 seti x=3
outsig 4
ifsig -5 then goto 4
type "Actual order is: 1 of each"
return
4 seti x=4
outsig -2
ifsig -5 then goto 5
type "Actual order is: 1 light ball"
return
5 seti x=5
outsig 5
ifsig -5 then goto 6
type "Actual order is: 1 dark ball, reversed"
return
6 seti x=6
outsig -3
ifsig -5 then goto 7
type "Actual order is: none"
return
7 seti x=7
outsig 2
ifsig -5 then goto 8
type "Actual order is: 1 dark ball"
return
8 seti x=8
outsig -4
ifsig -5 then goto 9
type "Actual order is: 1 light ball, reversed"
return
9 seti x=9
return
30 seti s=0
seti t=0
outsig 1
ifsig -1 then goto 31
ifsig -2 then goto 32
ifsig 4 then goto 33
seti t=t+2
33 ifsig 3 then goto 34
```

```
goto 32
34 seti t=t+2
32 seti s=1
31 return
82 pause 5
80 ifsig b then goto 81
aux a
waitfor b
goto 82
81 seti a=-a
aux a
return
49 gosub 70
goto 73
48 gosub 70
goto 72
70 seti b=-7
seti a=1
type "Checking if enough dark balls"
gosub 80
50 type "Getting a dark ball"
movep sbo
movep abo
movep do
movep adc
movep sbc
return
47 gosub 71
goto 73
46 gosub 71
goto 72
71 seti b=-8
seti a=1
type "Checking if enough light balls"
gosub 80
51 type "Getting a light ball"
movep sbo
movep alo
movep lo
movep alc
movep sbc
return
72 type "Placing ball on right side of pallet"
movep rac
movep rcc
movep rao
movep sbo
return
73 type "Placing ball on left side of pallet"
movep lac
movep lcc
movep lao
movep sbo
return
74 type "Emptying right side of pallet"
movep sbo
movep rao
movep rco
movep rac
5o movep sbc
movep amc
movep mc
movep emo
movep amo
movep sbo
```

```
return
75 type "Emptying left side of pallet"
moveo sbo
movep lao
movep lco
movep lac
goto 56
76 type "Transfering ball from left to right"
movep sbo
movep lao
movep lco
movep lac
movep rac
movep rcc
movep rao
movep sbo
return
77 type "Transfering ball from right to left"
movep sbo
movep rao
movep rco
movep rac
movep lac
movep lcc
movep lao
movep sbo
return
90 outsig 2
outsig 3
outsig 4
outsig -5
ifsig -5 then goto 57
seti b=6
seti a=2
type "Checking if a pallet is available"
gosub 80
59 type "Getting a pallet"
movep sbo
outsig 2
outsig 3
outsig 4
outsig -5
ifsig -5 then goto 57
movep apo
movep po
movep apc
movep sbc
movep acc
movep ac1
movep cc
movep aco
movep sbo
outsig 2
outsig 3
outsig 4
outsig -5
ifsig -5 then goto 57
type ""
type "Pallet misplaced--please help."
type ""
waitfor -5
57 return
91 type "Returning the pallet"
movep sbo
movep aco
moveo co
```

```
 movep acc
 movep anc
 movep nc
 movep aho
 movep sbo
 return
 rem
 rem point definitions
 rem
 movep po
 movep apc
 movep apo
 movep anc
 movep ano
 movep nc
 movep rcc
 movep rco
 movep rac
 movep rao
 movep ico
 movep icc
 movep iac
 movep iao
 movep ac1
 movep aco
 movep acc
 movep sbo
 movep sbc
 movep do
 movep adc
 movep ado
 movep io
 movep alo
 movep aic
 movep mc
 movep amo
 movep amc
 movep emo
 movep co
 movep cc
 rem END
```

em
File: WORKDOC Workcell program (non-executable), documented version.

Program description:

The Rhino Workcell simulates a typical palletizing and inspection process where the items to be palletized are specified by a remote device. In this case, if the inspection process determines that an order was filled incorrectly, the workcell will attempt to correct the order. Also, the Rhino Workcell will disassemble an order and replace all the parts so that it can repeat the process over and over.

In general, the palletizing process involves obtaining an order for 1 or 2 balls of either 1 or 2 colors, placing them on a pallet, inspecting them and returning them to their stations.

Specifically: The workcell will wait for an order to be placed at the order center. Once the single cycle or run keys are pressed the workcell will determine if all the necessary parts including the pallet are available. If they are not, the workcell will attempt to bring them into place by operating the vertical conveyor for needed dark or light balls, or the horizontal conveyor for pallets. Once the parts are available, the workcell will obtain a pallet and place it on the rotary carousel if a pallet is not already in place. If the pallet does not get seated correctly the workcell will notify the operator by printing a message to the screen. Then according to the order that was placed, the workcell will get and place the needed dark and/or light balls onto the pallet. The filled pallet is then sent to the inspection station where the order is checked to see that it matches the requested order. If the order is correct the accept lamp is turned on and the pallet is brought back to the robot for disassembly. If the order is found to be incorrect, the workcell will attempt to correct it. It should be noted that the order, prior to the inspection process can be manually modified in order to show the attempts to correct a wrong order. However, modifying the order after the inspection process will not be recognized by the workcell. During the above process, the screen will continually show the current status of the operation. The workcell can be operated in single cycle mode where a single order is placed and filled, or as a run of single cycles where the order is filled over and over again.

Some special notes...

A cycle is composed of bringing output line 1 low to latch the data present at the order center. This line also turns on the green LED at the order center to show that cycle is in operation. Therefore output line 1 should not be brought high again until the cycle is complete.

As a rule, taught points are named with labels ending in 'c' for gripper closed or 'o' for gripper open. In all movep commands, the gripper is executed first. Therefore a routine such as...

```
movep xxxo
movep xxxc
```

will save program space by not requiring an intermediate command such as...

```
movep xxxb
close -1
movep xxxc
```

If 'run continuous' mode is selected, pressing a new order will be accepted. That is, you can change the order during a run. Holding the single cycle selection down will operate in the same way as a 'run continuous' selection.

For single ball or mixed orders, the dark ball is placed on the right and/or the light ball is placed on the left side of the pallet.

The inspection station will not operate correctly if a pallet is not seated properly on the two pins on the platter of the rotary carousel that has the switches on either side of the pins. However, in normal operation, the workcell checks for this and notifies the operator of any malfunction. Since the inspection station is normally only active when an order is being inspected and a pallet is in place, this presents no problem.

Before running this program the user must be sure all connections have been made according to the workcell wiring diagram, that the aux 1 and aux 2 switches are in the down position and that the ball sorter mechanism's power supply is turned on. The user should check the ball sorter mechanism by dropping a few different colored balls into the chute at the very top of the vertical conveyor. If a bucket is in the way, you can move it either by manually turning the knurled knob on the vertical conveyor's motor or under Robotalk control using the direct execution mode and the aux commands. The user must also be sure the carousel and slide base are at their respective initial (home) positions. The operator can do this via the teach pendant system before running Robotalk. Refer to the start-up procedure sheet. The robot arm itself can be homed by answering yes when Robotalk asks if the robot is to be initialized. Once the robot has been homed, the operator should make sure the hand is staright up and down by manually moving it. Do not use the pendant to accomplish this. The program can be run by loading WORKI for the IBM PC or WORKA for the Apple IIe and pressing R followed by return.

Port definitions:

Inputs	Outputs
1 Order center data	1 Order center data latch
2 Order center data	2 Inspection station data
3 Order center data	3 Inspection station data
4 Order center data	4 Inspection station data
5 Inspection station data	5 Inspection station data
6 Pallet detect	6 No connection
7 Dark ball detect	7 Accept lamp
8 Light ball detect	8 Reject lamp

Input 5 is also used to detect if a pallet is seated properly on the rotary carousel.

Ports A-F: Standard XR-2 configuration.
Port G: Linear slide base.
Port H: Rotary carousel.

Aux 1 :Vertical conveyor (switch down).
Aux 2 :Horizontal conveyor (switch down).

Continued to WORKDOC1...
rem

```
62 if x=7 then goto 89    ;branch if correct
   gosub 88               ;reject lamp on
   if x=0 then goto 101   ;got 2 dark balls
   if x=1 then goto 115   ;got 1 of each reversed
   if x=2 then goto 121   ;got 2 light balls
   if x=3 then goto 101   ;got 1 of each
   if x=4 then goto 123   ;got 1 light ball
   if x=5 then goto 102   ;got 1 dark ball reversed
   if x=6 then goto 106   ;got none
   if x=8 then goto 109   ;got 1 light ball reversed
   goto 200               ;error-bad inspection station

rem Check &/or correct for 2 dark balls.

63 if x=0 then goto 89    ;branch if correct
   gosub 88               ;reject lamp on
   if x=1 then goto 109   ;got 1 of each reversed
   if x=2 then goto 112   ;got 2 light balls
   if x=3 then goto 122   ;got 1 of each
   if x=4 then goto 111   ;got 1 light ball
   if x=5 then goto 106   ;got 1 dark ball reversed
   if x=6 then goto 110   ;got none
   if x=7 then goto 107   ;got 1 dark ball
   if x=8 then goto 113   ;got 1 light ball reversed
   goto 200               ;error-bad inspection station

rem Check &/or correct for 1 light ball

64 if x=4 then goto 89    ;branch if correct
   gosub 88               ;reject lamp on
   if x=0 then goto 120   ;got 2 dark balls
   if x=1 then goto 116   ;got 1 of each reversed
   if x=2 then goto 100   ;got 2 light balls
   if x=3 then goto 100   ;got 1 of each
   if x=5 then goto 108   ;got 1 dark ball reversed
   if x=6 then goto 105   ;got none
   if x=7 then goto 126   ;got 1 dark ball
   if x=8 then goto 103   ;got 1 light ball reversed
   goto 200               ;error-bad inspection station

rem Check &/or correct for 2 light balls

65 if x=2 then goto 89    ;branch if correct
   gosub 88               ;reject lamp on
   if x=0 then goto 118   ;got 2 dark balls
   if x=1 then goto 108   ;got 1 of each reversed
   if x=3 then goto 114   ;got 1 of each
   if x=4 then goto 104   ;got 1 light ball
   if x=5 then goto 119   ;got 1 dark ball reversed
   if x=6 then goto 117   ;got none
   if x=7 then goto 127   ;got 1 dark ball
   if x=8 then goto 105   ;got 1 light ball reversed
   goto 200               ;error-bad inspection station

rem Accept/Reject lamp controls

89 outsig 7    ;turn on accept lamp
   outsig -8   ;turn off reject lamp
   type "Order is ACCEPTED"
   movep sbo   ;bring order back to robot for removal
   return
88 outsig 8    ;turn on reject lamp
   outsig -7   ;turn off accept lamp
   type "Order is REJECTED"
   movep sbo   ;bring order back to robot for removal
   return
```

```
rem Error-bad inspection station: Start over.

200 type ""
    type "Inspection station malfunctioning."
    type "Check it and restart the program."
    end

rem Continued to WORKDOC2
```

```
rem On return, if s=0 then no selection was made.  If s=1 then a
rem  selection was made & t contains the type of selection.
rem  t=0, 1 of each. t=1, 1 dark ball. t=2, 2 dark balls.
rem  t=3, 1 light ball. t=4, 2 light balls.

30 seti s=0                  ;select flag=no selection made
   seti t=0                  ;type flag=1 of each
   outsig 1                  ;latch data
   ifsig -1 then goto 31     ;branch if no selection made
   ifsig -2 then goto 32     ;branch if 1 of each
   ifsig 4 then goto 33      ;branch if dark ball
   seti t=t+2                ;light ball so offset t
33 ifsig 3 then goto 34      ;branch if 2 balls
   seti t=t+1                ;t=1 (1 dark), t=3 (1 light)
   goto 32
34 seti t=t+2                ;t=2 (2 dark), t=4 (2 light)
32 seti s=1                  ;select flag=selection made
31 return

rem Vertical/Horizontal conveyor operation.

rem Caller sets output line b. b=7, dark ball detect. b=8, light
rem  ball detect. b=6, pallet detect.
rem Caller sets aux a. a=1, vertical conveyor. a=2, horizontal.
rem If caller needs dark balls, caller should set b=-7, a=1.
rem If caller needs light balls, caller should set b=-8, a=1.
rem If caller needs a pallet, caller should set b=6, a=2.
rem When called, if item not present, the appropriate conveyor
rem  is turned on until item detected by optics.  A short delay
rem  is used after detection to ensure bounce doesn't give a
rem  false signal.  Conveyor is then turned off.
rem Line 80 is the entry point.

82 pause 5                   ;debounce
80 ifsig b then goto 81      ;return if item detected
   aux a                     ;turn on appropriate conveyor
   waitfor b                 ;wait for item to be detected
   goto 82                   ;delay then check again
81 seti a=-a                 ;change sign
   aux a                     ;turn off conveyor
   return

rem Ball handling routines. Get, place, empty, transfer.

rem Get a dark ball & place on left side.

49 gosub 70
   goto 73

rem Get a dark ball & place on right side.

48 gosub 70
   goto 72

rem Get a dark ball

70 seti b=-7    ;dark ball detect line
   seti a=1     ;vertical conveyor
   type "Checking if enough dark balls"
   gosub 80     ;ensure enough dark balls
50 type "Getting a dark ball"
   movep sbo    ;safe position, open
   movep ado    ;above dark ball, open
   movep do     ;at dark ball, open
   movep adc    ;above dark ball, closed
   movep sbc    ;safe position, closed
```

```
   return

rem Get a light ball & place on left

47 gosub 71
   goto 73

rem Get a light ball & place on right

46 gosub 71
   goto 72

rem Get a light ball

71 seti b=-8    ;light ball detect line
   seti a=1     ;vertical convevor
   type "Checking if enough light balls"
   gosub 80     ;ensure enough light balls
51 type "Getting a light ball"
   movep sbo    ;safe position, open
   movep alo    ;above light ball, open
   movep lo     ;at light ball, open
   movep alc    ;above light ball, closed
   movep sbc    ;safe position, closed
   return

rem Place ball on right.

72 type "Placing ball on right side of pallet"
   movep rac    ;above right side, closed
   movep rcc    ;at right side, closed
   movep rao    ;above right side, open
   movep sbo    ;safe position, open
   return

rem Place ball on left.

73 type "Placing ball on right side of pallet"
   movep lac    ;above left side, closed
   movep lcc    ;at left side, closed
   movep lao    ;above left side, open
   movep sbo    ;safe position, open
   return

rem Empty right side of pallet.

74 type "Empyting right side of pallet"
   movep sbo    ;safe position, open
   movep rao    ;above right side, open
   movep rco    ;at right side, open
   movep rac    ;above right side, closed
56 movep sbc    ;at safe position, closed
   movep amc    ;above ball return ramp, closed
   movep mc     ;at ball return ramp, closed
   movep emo    ;at empty position (putt), open
   movep amo    ;above ball return ramp, open
   movep sbo    ;safe position, open
   return

rem Empty left side of pallet.

75   type "Emptying left side of pallet"
   movep sbo    ;safe position, open
   movep lao    ;above left side, open
   movep lco    ;at left side, open
   movep lac    ;above left side, closed
```

```
    ---- ---      ;do the rest of it

 rem Transfer ball left to right

 76 type "Transfering ball from left to right"
    movep sbo    ;safe position, open
    movep lao    ;above left side, open
    movep lco    ;at left side, open
    movep lac    ;above left side, closed
    movep rac    ;above right side, closed
    movep rcc    ;at right side, closed
    movep rao    ;above right side, open
    movep sbo    ;safe position, open
    return

rem Transfer ball right to left.

77 type "Transfering ball from right to left"
   movep sbo    ;safe position, open
   movep rao     ;above right side, open
   movep rco    ;at right side, open
   movep rac    ;above right side, closed
   movep lac    ;above left side, closed
   movep lcc    ;at left side, closed
   movep lao    ;above left side, open
   movep sbo    ;safe position, open
   return

rem Continued to WORKDOC3
```

```
em
file: WORKDOC3   Continued from WORKDOC2

rem Get a pallet & place on carousel

90 outsig 2                 :check if pallet already on carousel
   outsig 3
   outsig 4
   outsig -5
   ifsig -5 then goto 57 :branch if already there
   seti b=6                 :pallet detect line
   seti a=2                 :horizontal conveyor
   type "Checking if a pallet is available"
   gosub 80                 :ensure have enough pallets
59 type "Getting a pallet"
   movep sbo                :safe position, open
   outsig 2                 :check if pallet already on carousel
   outsig 3
   outsig 4
   outsig -5
   ifsig -5 then goto 57 :branch if already there
   movep apo                :above pallet feed, open
   movep po                 :at pallet feed, open
   movep apc                :above pallet feed, closed
   movep sbc                :safe position, closed
   movep acc                :above center carousel, closed
   movep aci                :just above center carousel, closed
   movep cc                 :at center carousel, closed
   movep aco                :above center carousel, open
   movep sbo                :safe position, open
   outsig 2                 :check if pallet seated correctly
   outsig 3
   outsig 4
   outsig -5
   ifsig -5 then goto 57 :branch if seated properly
   type ""
   type "Pallet misplace--please help."
   type ""
   wait for -5
57 return

rem Return pallet to pallet return ramp.

91 type "Returning the pallet"
   movep sbo                :safe position, open
   movep aco                :above center carousel, open
   movep co                 :at center carousel, open
   movep acc                :above center carousel, closed
   movep ahc                :above pallet return ramp, closed
   movep hc                 :at pallet return ramp, closed
   movep aho                :above pallet return ramp, open
   movep sbo                :safe position, open
   return

rem Point definitions.

movep rac  :above right side of pallet at carousel, closed
movep rao  :above right side of pallet at carousel, open
movep rcc  :at right side of pallet at carousel, closed
movep rco  :at right side of pallet at carousel, open
movep lac  :above left side of pallet at carousel, closed
```

```
movep lao  ;above left side of pallet at carousel, open
movep lcc  ;at left side of pallet at carousel, closed
movep lco  ;at left side of pallet at carousel, open
movep alc  ;above light ball feed ramp, closed
movep alo  ;above light ball feed ramp, open
movep lo   ;at light ball feed ramp, open
movep adc  ;above dark ball feed ramp, closed
movep ado  ;above dark ball feed ramp, open
movep do   ;at dark ball feed ramp, open
movep sbc  ;safe position, closed (above all equipment)
movep sbo  ;safe position, open (above all equipment)
movep amc  ;above ball return ramp, closed
movep amo  ;above ball return ramp, open
movep mc   ;at ball return ramp, closed
movep emo  ;at ball return ramp, open (putting move)
movep acc  ;above center of pallet at carousel, closed
movep aco  ;above center of pallet at carousel, open
movep aci  ;just above center of pallet at carousel, closed
movep cc   ;at center of pallet at carousel, closed
movep co   ;at center of pallet at carousel, open
movep apc  ;above pallet feed, closed
movep apo  ;above pallet feed, open
movep po   ;at pallet feed, open
movep anc  ;above pallet return ramp, closed
movep ano  ;above pallet return ramp, open
movep hc   ;at pallet return ramp, closed

rem END
```

```
EM
REM FILE: WORKA   APPLE IIe EXECUTABLE WORKCELL PROGRAM
REM
OUTSIG -1
OUTSIG 1
26 CLS
TYPE "PLACE ORDER"
20 OUTSIG -1
OUTSIG -7
OUTSIG -8
OUTSIG 1
OUTSIG 2
OUTSIG 3
IFSIG -1 THEN GOTO 26
IFSIG -2 THEN GOTO 33
IFSIG 4 THEN GOTO 32
TYPE "ORDER IS 2 LIGHT BALLS"
GOSUB 90
GOSUB 71
GOSUB 72
GOSUB 71
GOSUB 73
OUTSIG -4
OUTSIG -5
GOTO 30
32 TYPE "ORDER IS 2 DARK BALLS"
GOSUB 90
GOSUB 70
GOSUB 72
GOSUB 70
GOSUB 73
OUTSIG 4
OUTSIG 5
GOTO 30
33 TYPE "ORDER IS 1 OF EACH"
GOSUB 90
GOSUB 70
GOSUB 72
GOSUB 71
GOSUB 73
OUTSIG 4
OUTSIG -5
30 GOSUB 95
GOSUB 75
TYPE "RETURN PALLET"
MOVEP SBO
MOVEP ACO
MOVEP CO
MOVEP ACC
MOVEP AHC
MOVEP HC
MOVEP AHO
MOVEP SBO
GOTO 20
95 TYPE "CHECKING THE ORDER"
MOVEP IS
IFSIG 5 THEN GOTO 96
OUTSIG 7
OUTSIG -8
TYPE "REJECTED"
RETURN
```

```
 96 OUTSIG -7
 OUTSIG 8
 TYPE "ACCEPTED"
 RETURN
 75 TYPE "EMPTY LEFT SIDE"
 MOVEP SBO
 MOVEP LAO
 MOVEP LCO
 MOVEP LAC
 GOSUB 56
 TYPE "EMPTY RIGHT SIDE"
 MOVEP SBO
 MOVEP RAO
 MOVEP RCO
 MOVEP RAC
 56 MOVEP SBC
 MOVEP AMC
 MOVEP MC
 MOVEP EMO
 MOVEP AMO
 MOVEP SBO
 RETURN
 90 SETI B=6
 SETI A=2
 TYPE "CHECK FOR PALLET"
 GOSUB 80
 TYPE "GET PALLET"
 MOVEP SBO
 MOVEP APO
 MOVEP PO
 MOVEP APC
 MOVEP SBC
 MOVEP ACC
 MOVEP ACI
MOVEP CC
 MOVEP ACO
 MOVEP SBO
 RETURN
 70 SETI B=-7
 SETI A=1
 TYPE "CHECK FOR DARK BALL"
 GOSUB 80
 TYPE "GET DARK BALL"
 MOVEP SBO
 MOVEP ADO
 MOVEP DO
 MOVEP ADC
 MOVEP SBC
 RETURN
 71 SETI B=-8
 SETI A=1
 TYPE "CHECK FOR LIGHT BALL"
 GOSUB 80
 TYPE "GET LIGHT BALL"
 MOVEP SBO
 MOVEP ALO
 MOVEP LO
 MOVEP ALC
 MOVEP SBC
 RETURN
 72 TYPE "PLACE ON RIGHT"
 MOVEP RAC
 MOVEP RCC
 MOVEP RAO
 MOVEP SBO
 RETURN
```

```
73 TYPE "PLACE ON LEFT"
MOVEP LAC
MOVEP LCC
MOVEP LAO
MOVEP SBO
RETURN
82 PAUSE 5
80 IFSIG B THEN GOTO 81
AUX A
WAITFOR B
GOTO 82
81 SETI A=-A
AUX A
RETURN
```

```
EM
REM FILE: WORKDA  APPLE IIe  WORKCELL PROGRAM, DOCUMENTED VERSION.
REM
REM WORKA IS THE EXECUTABLE PROGRAM.
REM
REM REFER TO 'WORKDOC' FOR A MORE COMPLETE DESCRIPTION OF THE
REM  OPERATION OF THE WORKCELL.
REM
   OUTSIG -1                          ;INITIALIZE ORDER CENTER (CLEAR DATA)
   OUTSIG 1
26 CLS
   TYPE "PLACE ORDER"
20 OUTSIG -1                          ;RESET LATCH LINE
   OUTSIG -7                          ;TURN OFF ACCEPT LAMP
   OUTSIG -8                          ;TURN OFF REJECT LAMP
   OUTSIG 1                           ;LATCH ORDER CENTER DATA
   OUTSIG 2                           ;SET UP PARTIAL DATA AT INSPECT STATION
   OUTSIG 3
   IFSIG -1 THEN GOTO 26              ;BRANCH IF NO ORDER PLACED
   IFSIG -2 THEN GOTO 33              ;BRANCH IF 1 OF EACH
   IFSIG 4 THEN GOTO 32               ;BRANCH IF 2 DARK BALLS
REM
   TYPE "ORDER IS 2 LIGHT BALLS"
   GOSUB 90                           ;GET A PALLET
   GOSUB 71                           ;GET A LIGHT BALL
   GOSUB 72                           ;PLACE ON RIGHT SIDE OF PALLET
   GOSUB 71                           ;GET A LIGHT BALL
   GOSUB 73                           ;PLACE ON LEFT SIDE OF PALLET
   OUTSIG -4                          ;SET UP REST OF INSPECTION STATION DATA
   OUTSIG -5
   GOTO 30                            ;DO THE REST OF IT
REM
32 TYPE "ORDER IS 2 DARK BALLS"
   GOSUB 90                           ;GET A PALLET
   GOSUB 70                           ;GET A DARK BALL
   GOSUB 72                           ;PLACE ON RIGHT SIDE OF PALLET
   GOSUB 70                           ;GET A DARK BALL
   GOSUB 73                           ;PLACE ON LEFT SIDE OF PALLET
   OUTSIG 4                           ;SET UP REST OF INSPECTION STATION DATA
   OUTSIG 5
   GOTO 30                            ;DO THE REST OF IT
REM
33 TYPE "ORDER IS 1 OF EACH"
   GOSUB 90                           ;GET A PALLET
   GOSUB 70                           ;GET A DARK BALL
   GOSUB 72                           ;PLACE ON RIGHT SIDE OF PALLET
   GOSUB 71                           ;GET A LIGHT BALL
   GOSUB 73                           ;PLACE ON LEFT SIDE OF PALLET
   OUTSIG 4                           ;SET UP REST OF INSPECTION STATION DATA
   OUTSIG -5
REM
30 GOSUB 95                           ;INSPECT THE ORDER
   GOSUB 75                           ;EMPTY THE PALLET
   TYPE "RETURN THE PALLET"
   MOVEP SBO                          ;SAFE POSITION
   MOVEP ACO                          ;ABOVE CENTER CAROUSEL
   MOVEP CO                           ;AT CENTER CAROUSEL
   MOVEP ACC                          ;ABOVE CENTER CAROUSEL
   MOVEP AHC                          ;ABOVE PALLET RETURN RAMP
   MOVEP HC                           ;AT PALLET RETURN RAMP
   MOVEP AHO                          ;ABOVE PALLET RETURN RAMP
```

```
   GOTO 20                          ;START ALL OVER
REM
REM INSPECT THE ORDER
95 TYPE "CHECKING THE ORDER"
   MOVEP IS                         ;BRING PALLET TO INSPECTION STATION
   IFSIG 5 THEN GOTO 96             ;BRANCH IF ORDER IS CORRECT
   OUTSIG -7                        ;TURN OFF ACCEPT LAMP
   OUTSIG 8                         ;TURN ON REJECT LAMP
   TYPE "REJECTED"
   RETURN
96 OUTSIG 7                         ;TURN ON ACCEPT LAMP
   OUTSIG -8                        ;TURN OFF REJECT LAMP
   TYPE "ACCEPTED"
   RETURN
REM
REM EMPTY THE PALLET
75 TYPE "EMPTY LEFT SIDE"
   MOVEP SBO                        ;SAFE POSITION
   MOVEP LAO                        ;ABOVE LEFT SIDE
   MOVEP LCO                        ;AT LEFT SIDE
   MOVEP LAC                        ;ABOVE LEFT SIDE
   GOSUB 56                         ;GIVE BALL TO BALL RETURN RAMP
   TYPE "EMPTY RIGHT SIDE"
   MOVEP SBO                        ;SAFE POSITION
   MOVEP RAO                        ;ABOVE RIGHT SIDE
   MOVEP RCO                        ;AT RIGHT SIDE
   MOVEP RAC                        ;ABOVE RIGHT SIDE
REM
REM GIVE BALL TO BALL RETURN RAMP
56 MOVEP SBC                        ;SAFE POSITION
   MOVEP AMC                        ;ABOVE BALL RETURN RAMP
   MOVEP MC                         ;AT BALL RETURN RAMP
   MOVEP EMO                        ;PUSH BALL DOWN RAMP
   MOVEP AMO                        ;ABOVE BALL RETURN RAMP
   MOVEP SBO                        ;SAFE POSITION
   RETURN
REM
REM GET A PALLET
90 SETI B=6                         ;PALLET INPUT LINE
   SETI A=2                         ;HORIZONTAL CONVEYOR
   TYPE "CHECK FOR PALLET"
   GOSUB 80                         ;ENSURE PALLET IN PLACE
   TYPE "GET PALLET"
   MOVEP SBO                        ;SAFE POSITION
   MOVEP APO                        ;ABOVE PALLET FEED
   MOVEP PO                         ;AT PALLET FEED
   MOVEP APC                        ;ABOVE PALLET FEED
   MOVEP SBC                        ;SAFE POSITION
   MOVEP ACC                        ;ABOVE CENTER CAROUSEL
   MOVEP ACI                        ;CLOSER YET
   MOVEP CC                         ;AT CENTER CAROUSEL
   MOVEP ACO                        ;ABOVE CENTER CAROUSEL
   MOVEP SBO                        ;SAFE POSITION
   RETURN
REM
REM GET A DARK BALL
70 SETI B=-7                        ;DARK BALL INPUT LINE
   SETI A=1                         ;VERTICAL CONVEYOR
   TYPE "CHECK FOR DARK BALL"
   GOSUB 80                         ;ENSURE ENOUGH DARK BALLS
   TYPE "GET DARK BALL"
   MOVEP SBO                        ;SAFE POSITION
   MOVEP ADO                        ;ABOVE DARK BALL FEED
   MOVEP DO                         ;AT DARK BALL FEED
   MOVEP ADC                        ;ABOVE DARK BALL FEED
```

```
    MOVEP SBC                       ;SAFE POSITION
    RETURN
REM
REM GET A LIGHT BALL
71 SETI B=-8                        ;LIGHT BALL INPUT LINE
   SETI A=1                         ;VERTICAL CONVEYOR
   TYPE "CHECK FOR LIGHT BALL"
   GOSUB 80                         ;ENSURE ENOUGH LIGHT BALLS
   MOVEP SBO                        ;SAFE POSITION
   MOVEP ALO                        ;ABOVE LIGHT BALL FEED
   MOVEP LO                         ;AT LIGHT BALL FEED
   MOVEP ALC                        ;ABOVE LIGHT BALL FEED
   MOVEP SBC                        ;SAFE POSITION
   RETURN
REM
REM PLACE BALL ON RIGHT SIDE OF PALLET
72 TYPE "PLACE ON RIGHT"
   MOVEP RAC                        ;ABOVE RIGHT SIDE
   MOVEP RCC                        ;AT RIGHT SIDE
   MOVEP RAO                        ;ABOVE RIGHT SIDE
   MOVEP SBO                        ;SAFE POSITION
   RETURN
REM
REM PLACE BALL ON LEFT SIDE OF PALLET
73 TYPE "PLACE ON LEFT"
   MOVEP LAC                        ;ABOVE LEFT SIDE
   MOVEP LCC                        ;AT LEFT SIDE
   MOVEP LAO                        ;ABOVE LEFT SIDE
   MOVEP SBO                        ;SAFE POSITION
   RETURN
REM
REM ENSURES ENOUGH ITEMS ARE AVAILABLE
REM B=INPUT LINE TO CHECK
REM A=CONVEYOR TO CONTROL
REM LINE 80 IS THE ENTRY POINT
82 PAUSE 5                          ;DELAY TO DEBOUNCE ITEM
80 IFSIG B THEN GOTO 81             ;ITEM IS PRESENT
   AUX A                            ;TURN ON CONVEYOR A
   WAITFOR B                        ;WAIT FOR ITEM
   GOTO 82                          ;DEBOUNCE IT AND MAKE SURE IT'S THERE
81 SETI A=-A                        ;CHANGE SIGN
   AUX A                            ;TURN OFF CONVEYOR A
   RETURN
REM
REM POINT DEFINITIONS
REM
REM POINTS ENDING WITH 'O' MEAN THE GRIPPER IS OPEN
REM POINTS ENDING WITH 'C' MEAN THE GRIPPER IS CLOSED
REM
REM SBO  SAFE POSITION
REM SBC
REM ACO  ABOVE PALLET POSITION AT CAROUSEL
REM ACC
REM CO   AT PALLET POSITION AT CAROUSEL
REM CC
REM ACI  BETWEEN ACO AND CO
REM AHC  ABOVE PALLET RETURN RAMP
REM AHO
REM HC   AT PALLET RETURN RAMP
REM LCO  AT LEFT SIDE OF PALLET AT CAROUSEL
REM LCC
REM LAO  ABOVE LEFT SIDE OF PALLET AT CAROUSEL
REM LAC
REM RCO  AT RIGHT SIDE OF PALLET AT CAROUSEL
REM RCC
REM RAO  ABOVE RIGHT SIDE OF PALLET AT CAROUSEL
```

```
REM RAC
REM AMC   ABOVE BALL RETURN RAMP
REM AMO
REM MC    AT BALL RETURN RAMP
REM EMO   AT BALL RETURN RAMP, PUSH POSITION
REM APO   ABOVE PALLET FEED AT HORIZONTAL CONVEYOR
REM APC
REM PO    AT PALLET FEED AT HORIZONTAL CONVEYOR
REM ADO   ABOVE DARK BALL FEED
REM ADC
REM DO    AT DARK BALL FEED
REM ALO   ABOVE LIGHT BALL FEED
REM ALC
REM LO    AT LIGHT BALL FEED
REM
END
```

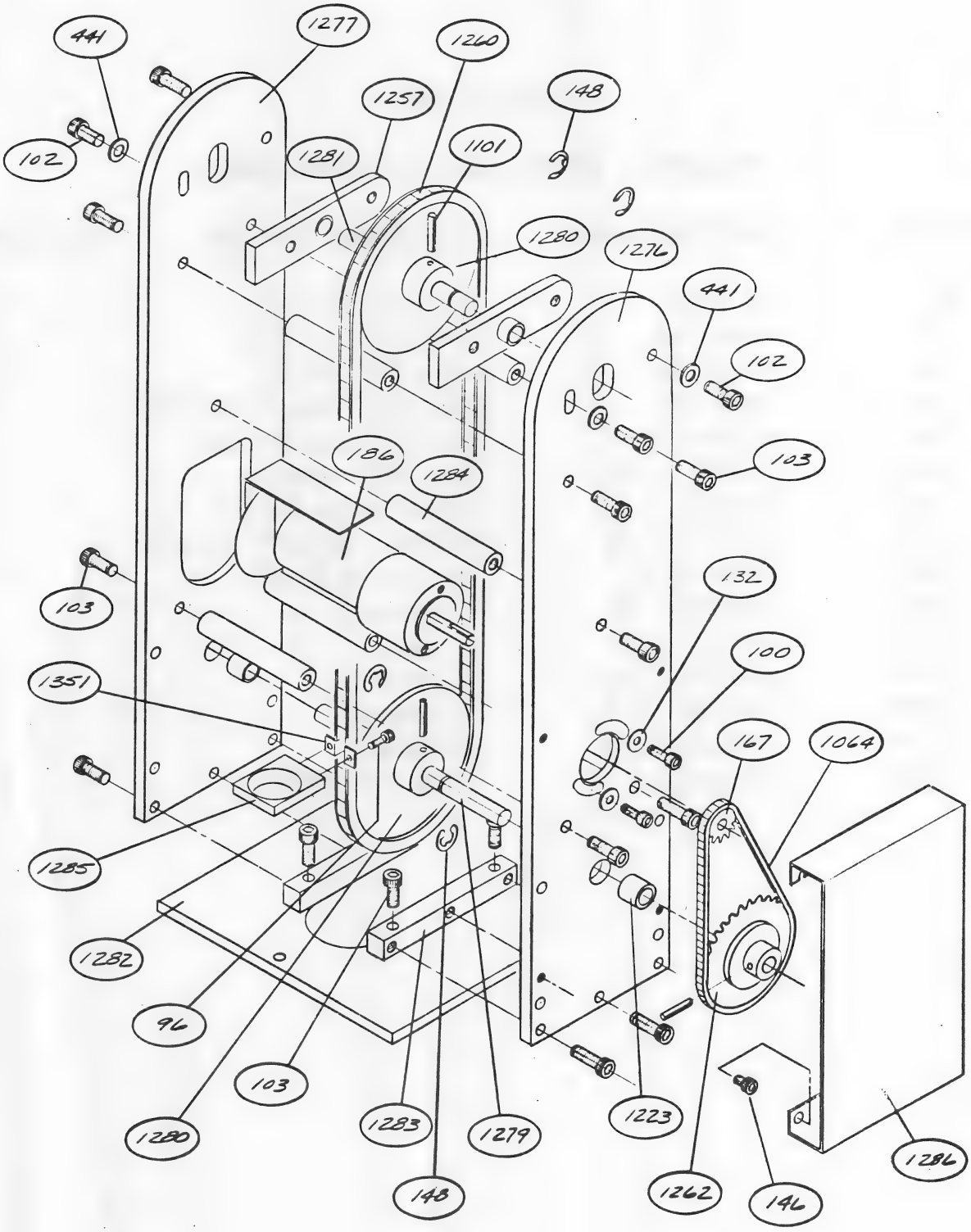
PARTS LISTS

FIGURE 2: WORK CELL POWER SUPPLY

FIGURE	PART NUMBER	PART DESCRIPTION	QUANTITY
99	15-1-99	10-32 x 3/8 SHCS	2
103	15-1-103	1/4-20 x 3/4 SHCS	4
109	15-2-109	6-32 x 1/4 BHCS	4
129	15-7-127	8-32 x 3/8 Chrome Phillips	2
794	30-149-794	Corcom Power Module	1
1025	30-252-1025	Fuse 3AG 1 amp SB	1
1143	30-120-1143	Power Supply 12VDC	1
1225	99-131-1225	WC Color sorter PCB assy	1
1250	15-2-1250	10-32 x 3/8 BHCS	4
1290	50-306-1290	PS housing	1
1291	50-306-1291	PS base	1
1292	50-306-1292	PS block	2
1293	50-306-1293	PS Spacer	1
1294	50-306-1294	PS Cover	1
1352	15-2-1352	10-32 x 1/2 BHCS	2

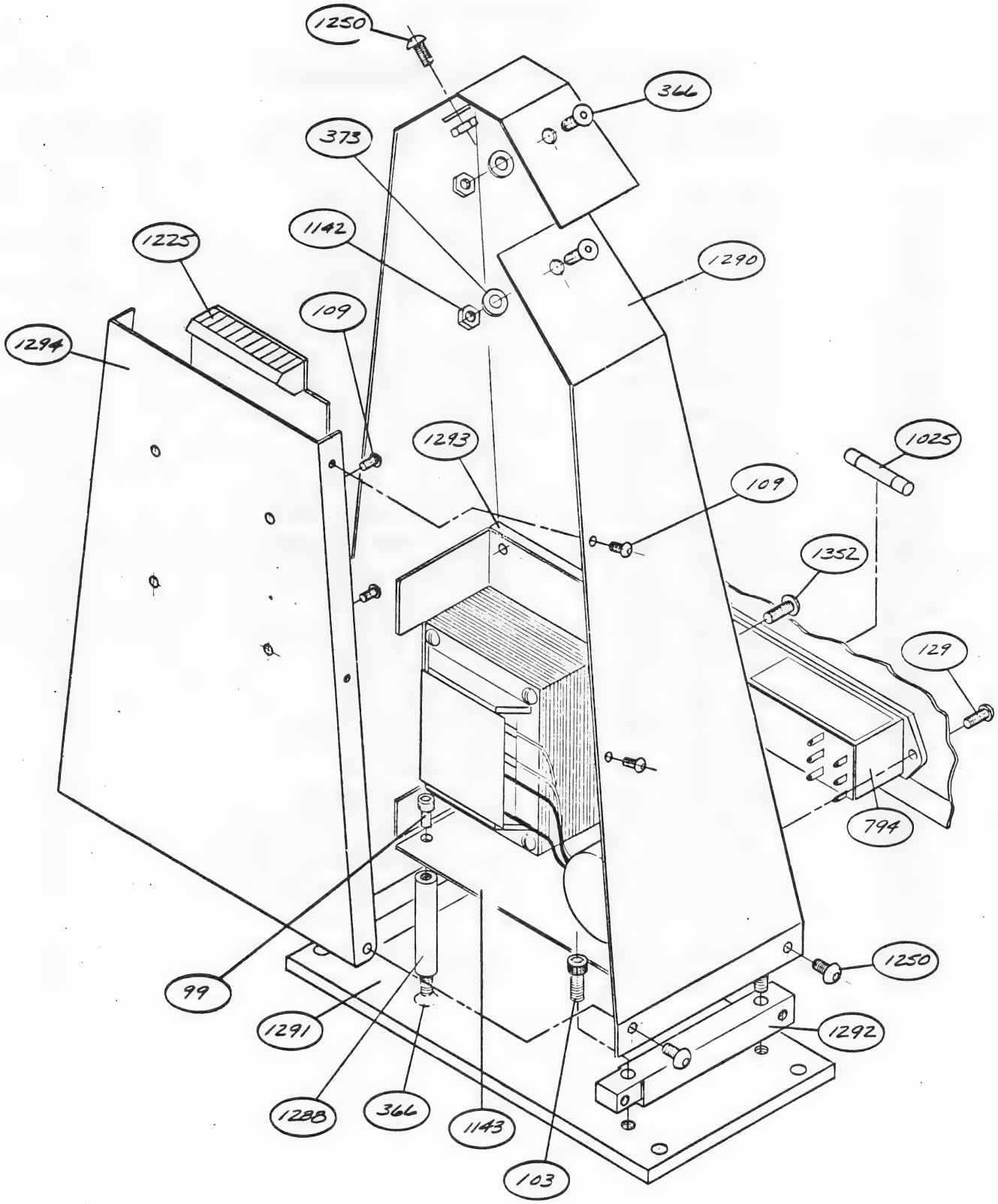
VERTICAL CONVEYOR

FIGURE 1



POWER SUPPLY

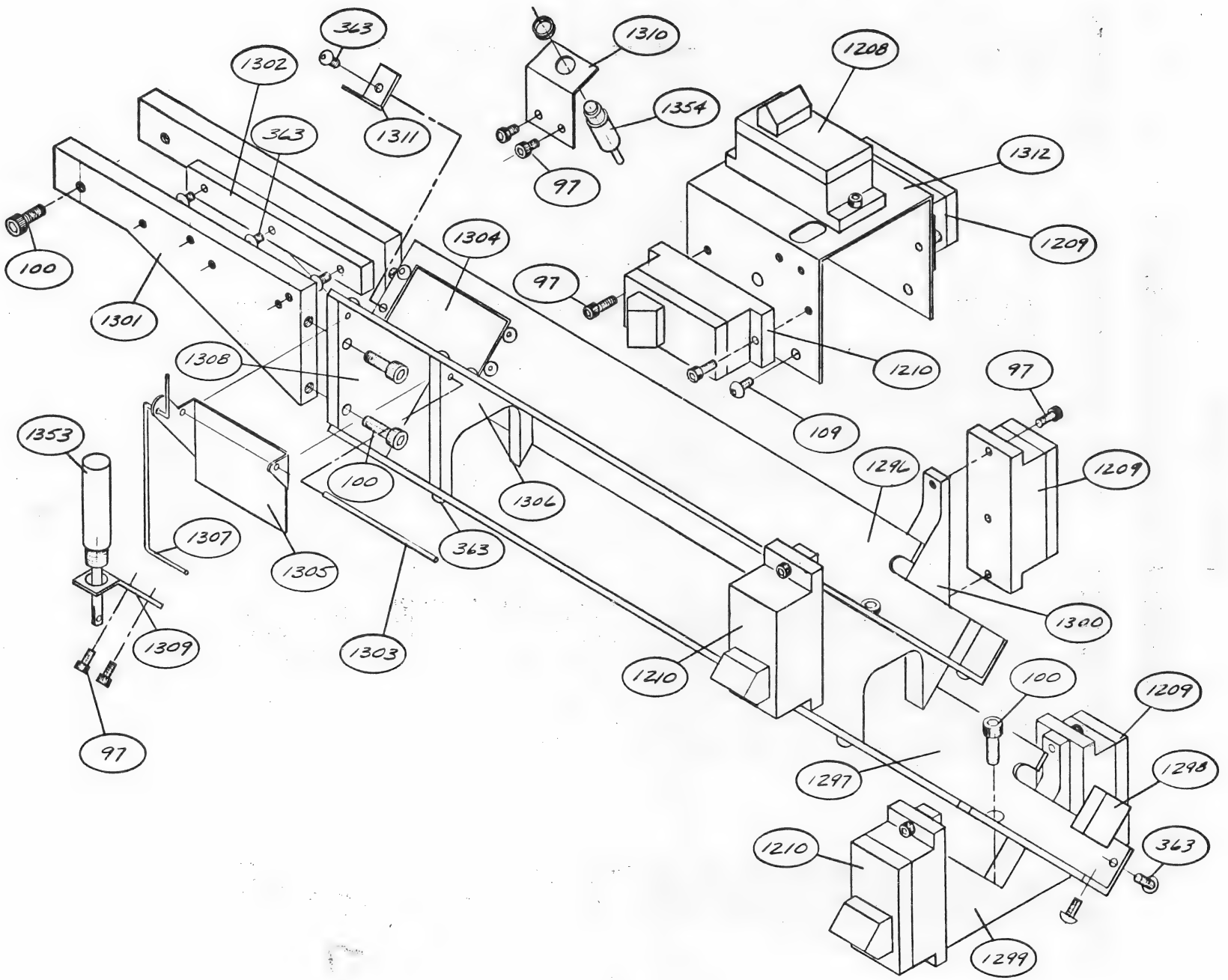
FIGURE 2



PARTS LISTS

FIGURE 3: BALL TRACK ASSEMBLY

FIGURE	PART NUMBER	PART DESCRIPTION	QUANTITY
97	15-1-97	6-32 x 3/8 SHCS	20
100	15-1-100	10-32 x 1/2 SHCS	8
109	15-2-109	6-32 x 1/4 BHCS	6
363	15-2-363	6-32 x 1/2 BHCS	12
1208	99-999-1208	Optics module Level Detector	1
1209	99-999-1209	Optics module Transmitter	3
1210	99-999-1210	Optics module Receiver	3
1296	50-306-1296	Upper ball track	1
1297	50-306-1297	Lower ball track	1
1298	50-306-1298	Ball track stop block	1
1299	50-306-1299	Optics module plate 1	1
1300	50-306-1300	Optics module plate 2	1
1301	50-306-1301	Ball track side plate	2
1302	50-306-1302	Ball track guide	2
1323	50-306-1303	Trap door pivot shaft	2
1304	50-306-1304	Trap door right	1
1305	50-306-1305	Trap door left	1
1306	50-306-1306	Door front support	1
1307	50-306-1307	Trap door link	2
1308	50-306-1308	Door rear support	1
1309	50-306-1309	4 x 12 Solenoid bracket	2
1310	50-306-1310	3.5 x 9 Solenoid bracket	1
1311	50-306-1311	Trap door stop plate	1
1312	50-306-1312	Ball sorter cover	1
1353	50-306-1353	Solenoid 4 x 12	2
1354	50-306-1354	Solenoid 3.5 x 9	1



UPPER & LOWER BALL TRACK

FIGURE 3

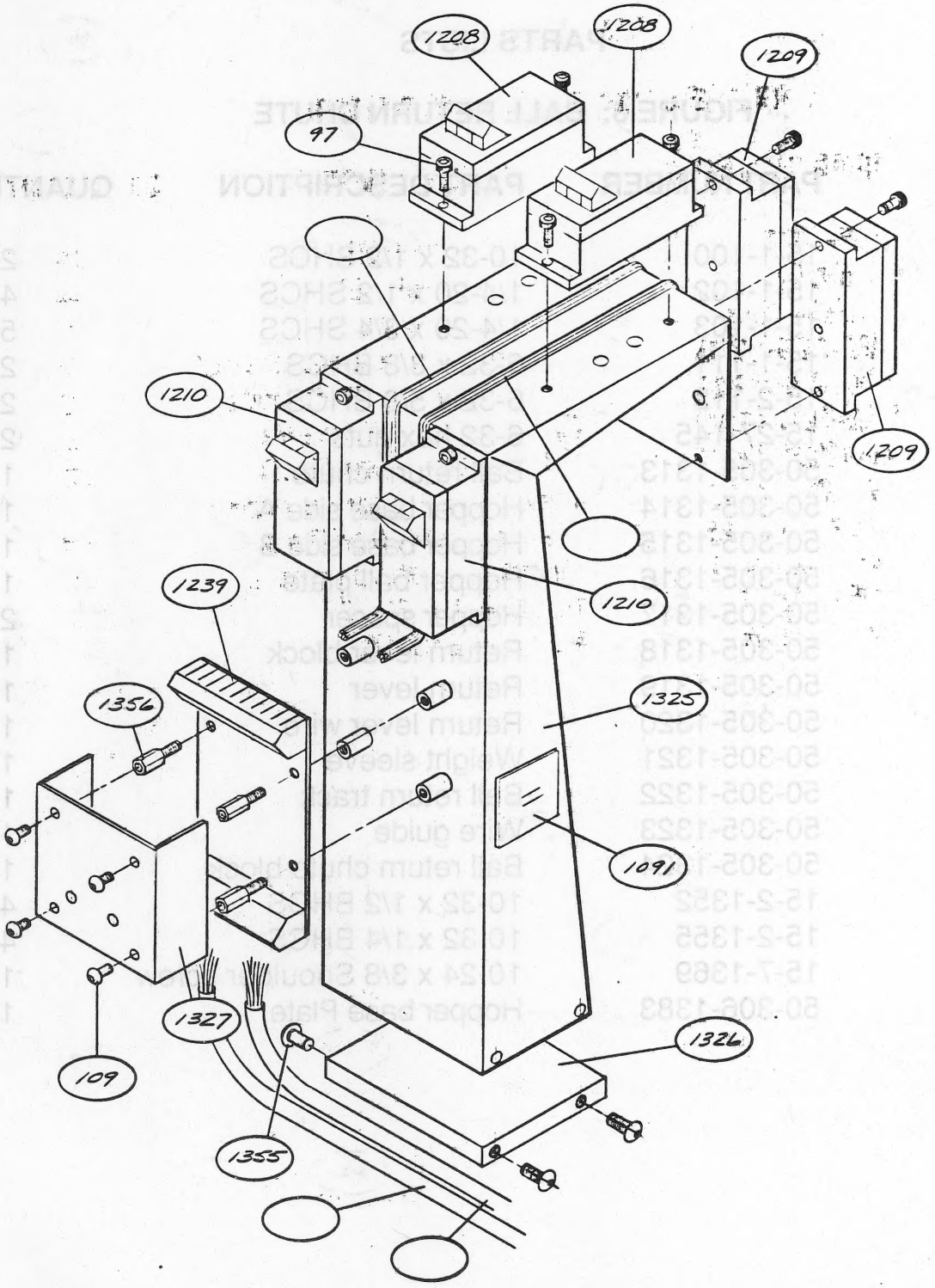
PARTS LISTS

FIGURE 4: PALLET RETURN RAMP

FIGURE	PART NUMBER	PART DESCRIPTION	QUANTITY
136	15-23-136	#6 Nylon washer thin	88
1142	15-27-1142	10-32 hex nut	2
1250	15-02-1250	10-32 x 3/8 BHCS	2
1320	50-306-1328	Roller track 1	1
1329	50-306-1329	Roller wheel	44
1330	50-306-1330	Roller track 2	2
1332	50-306-1332	Support #1	1
1333	50-306-1333	Base #1	1
1334	50-306-1334	Support #2	1
1335	50-306-1335	Base #1	1
1336	50-306-1336	Roller track bracket	1
1337	50-306-1337	Side Plate	2
1359	15-70-1335	0.125 x 0.500 Dowel Pin	44

INSPECTION STATION

FIGURE 5



PARTS LISTS

FIGURE 6: BALL RETURN CHUTE

FIGURE	PART NUMBER	PART DESCRIPTION	QUANTITY
100	15-1-100	10-32 x 1/2 SHCS	2
102	15-1-102	1/4-20 x 1/2 SHCS	4
103	15-1-103	1/4-20 x 3/4 SHCS	5
111	15-1-111	6-32 x 3/8 BHCS	2
112	15-2-112	6-32 x 5/8 BHCS	2
145	15-27-145	6-32 hex nuts	2
1313	50-305-1313	Ball return chute	1
1314	50-305-1314	Hopper base side A	1
1315	50-305-1315	Hopper base side B	1
1316	50-305-1316	Hopper ball plate	1
1317	50-305-1317	Hopper spacer	2
1318	50-305-1318	Return lever block	1
1319	50-305-1319	Return lever	1
1320	50-305-1320	Return lever wire	1
1321	50-305-1321	Weight sleeve	1
1322	50-305-1322	Ball return track	1
1323	50-305-1323	Wire guide	1
1324	50-305-1324	Ball return chute block	1
1352	15-2-1352	10-32 x 1/2 BHCS	4
1355	15-2-1355	10-32 x 1/4 BHCS	4
1369	15-7-1369	10-24 x 3/8 Shoulder screw	1
1383	50-306-1383	Hopper base Plate	1

BALL RETURN & HOPPER

FIGURE 6